Appendix H

Number

APPENDIX H

TECHNICAL MEMORANDUM: GROUNDWATER CODE SELECTION FOR THE TAN GROUNDWATER REMEDIAL INVESTIGATION/FEASIBILITY STUDY

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ABSTRACT

This memorandum addresses the proposed contaminant transport modeling effort for the Remedial Investigation/Feasibility Study for the Test Area North (TAN) Groundwater Operable Unit at the Idaho National Engineering Laboratory. This memorandum reviews in detail the geologic, hydrologic, and computational factors influencing the model selection process, thus summarizing the current understanding of the TAN groundwater flow system. Following that summary, a detailed description of the code selection criteria and results of the application of these criteria to various flow and transport codes are presented. On the basis of the code selection process, recommendations and associated considerations are given. As a result of this process, we (a) recommend taking a two-dimensional areal vertically integrated, transient, heterogeneous, free-surface approach, (b) suggest that there are no codes in their current form available for this type of flow and transport modeling; (c) conclude that any code selected will require some degree of modification, and (d) conclude that modifying codes that were developed at EG&G Idaho (i.e. FLASH/FLAME) for this modeling effort would be much more efficient than to modify other available codes.

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H-1. INTRODUCTION

The purpose of this technical memorandum is to select a numerical code for use in predicting the fate of contaminants in the groundwater at the Test Area North (TAN) site. First, we review the factors influencing numerical modeling of flow and transport of contaminants at TAN. On the basis of these factors, flow and transport codes are screened in order to select the one that will best simulate (or predict) the fate and transport of groundwater contaminants at TAN. Following the code selection results, this memorandum presents an implementation schedule based upon the code selection process.

The structure of this report is hierarchial. First, the current understanding of the TAN flow system is reviewed by examining (a) the geographical location with respect to natural recharge areas, (b) the historical pumping and recharge information, (c) the geological descriptions of the basalts and sedimentary interbeds with respect to the wells penetrating the aquifer system, and (d) the hydrologic properties and history of the water levels at TAN. The TAN Remedial Investigation/Feasibility Study (RI/FS) Work Plan (EG&G Idaho, 1992) presents the bulk of this background information in a more general context. Here, much of the geographic, geologic, and hydrologic information is represented as it pertains directly to predicting the fate of the organics and radionuclides existing in the TAN groundwater.

After presenting this necessary background information, the features of this complex flow system are tied into the flow and transport modeling process by examining a previous modeling effort (see Section H-6). The previous modeling effort serves to illustrate many of the physical features that must be incorporated into a realistically predictive model of flow and transport in the TAN groundwater system.

In Section H-7, the physical and numerical modeling requirements are presented. A numerical statement of the mathematical problem is given in Section H-8.

A large selection of public and private domain flow and transport codes are reviewed. The codes are presented in terms of our modeling objectives.

Each code is compared against the numerical modeling requirements presented in Section H-7. Codes meeting the qualifications are reviewed further, while those not meeting the basic requirements are dropped from further consideration.

On the basis of the entire code screening process, scheduling considerations, and modeling objectives, Section H-10 lists modeling recommendations for this operable unit.

H-2. GEOGRAPHY

The land surface at TAN is relatively flat with predominant relief consisting of volcanic vents (buttes) and unevenly surfaced and fissured basalt lava flows. TAN lies in a topographic depression between the base of the Lemhi range to the northwest, the Beaverhead Mountains to the northeast, and the Snake River drainage to the southeast. The elevation ranges from a low in this area of 4,774 ft on the Birch Creek playa floor to a high of 5,064 ft on top of Circular Butte.

The TAN site is down-gradient of the terminus of Birch Creek (Figure H-1), and up-gradient of the terminus of the Little Lost and Big Lost rivers. These rivers drain mountain watersheds existing to the north and northwest of the Idaho National Engineering Laboratory (INEL). In general, most of the flow from the Little Lost River and Birch Creek are diverted for irrigation purposes before reaching the INEL. However, historically, in high flow years and more often in recent years, Birch Creek actually flows into the Birch Creek Playa (Figure H-2) and then infiltrates. During years of high flow, the Little Lost River also flows onsite. In addition to being near these potential recharge areas, local rainfall and snowmelt during spring months contributes to the recharge in the vicinity of TAN. This recharge causes the water-table elevation to vary as discussed below.

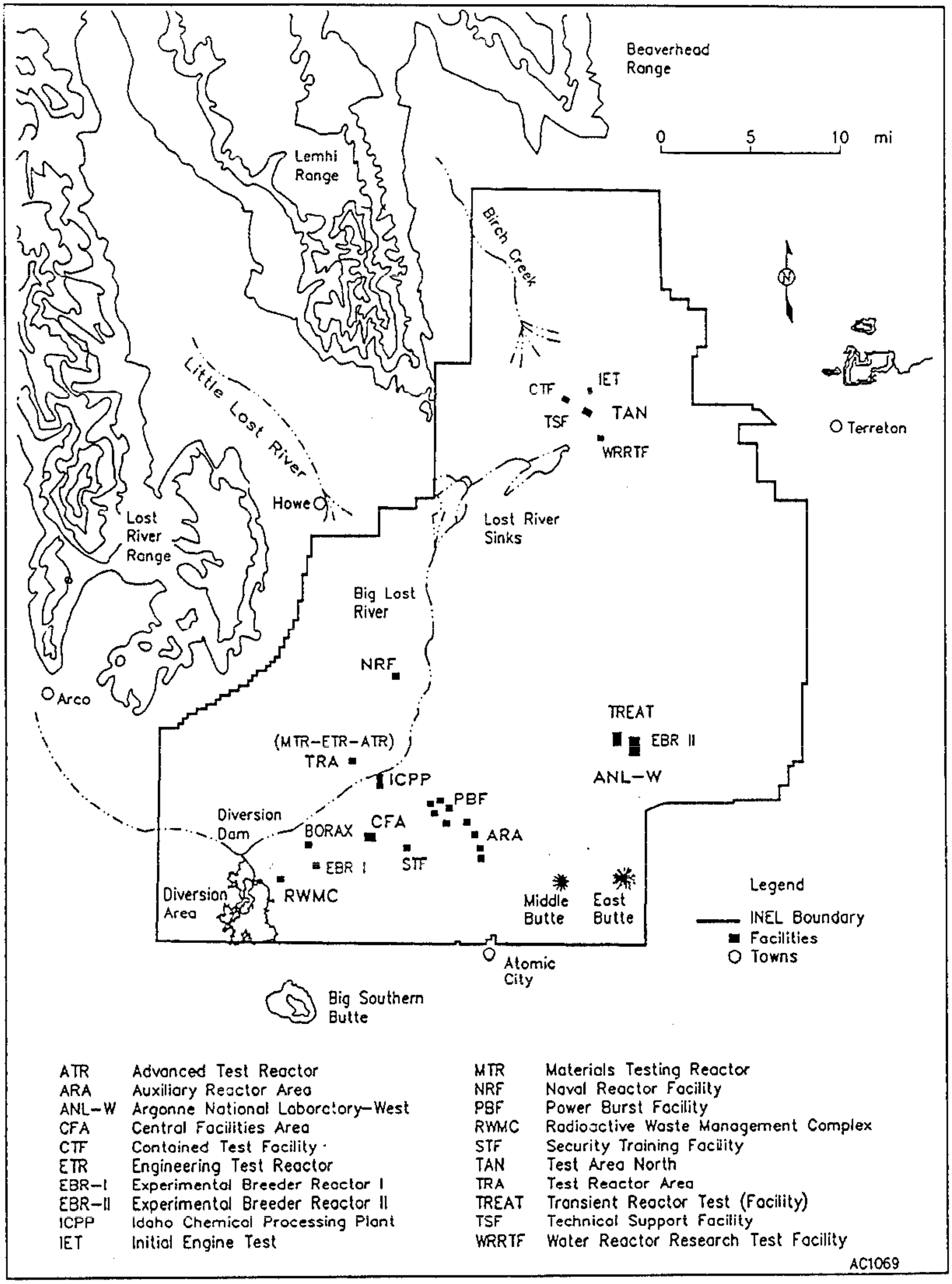


Figure H-1. Relative location of TAN with respect to Birch Creek, the Little Lost River, and the Big Lost River.

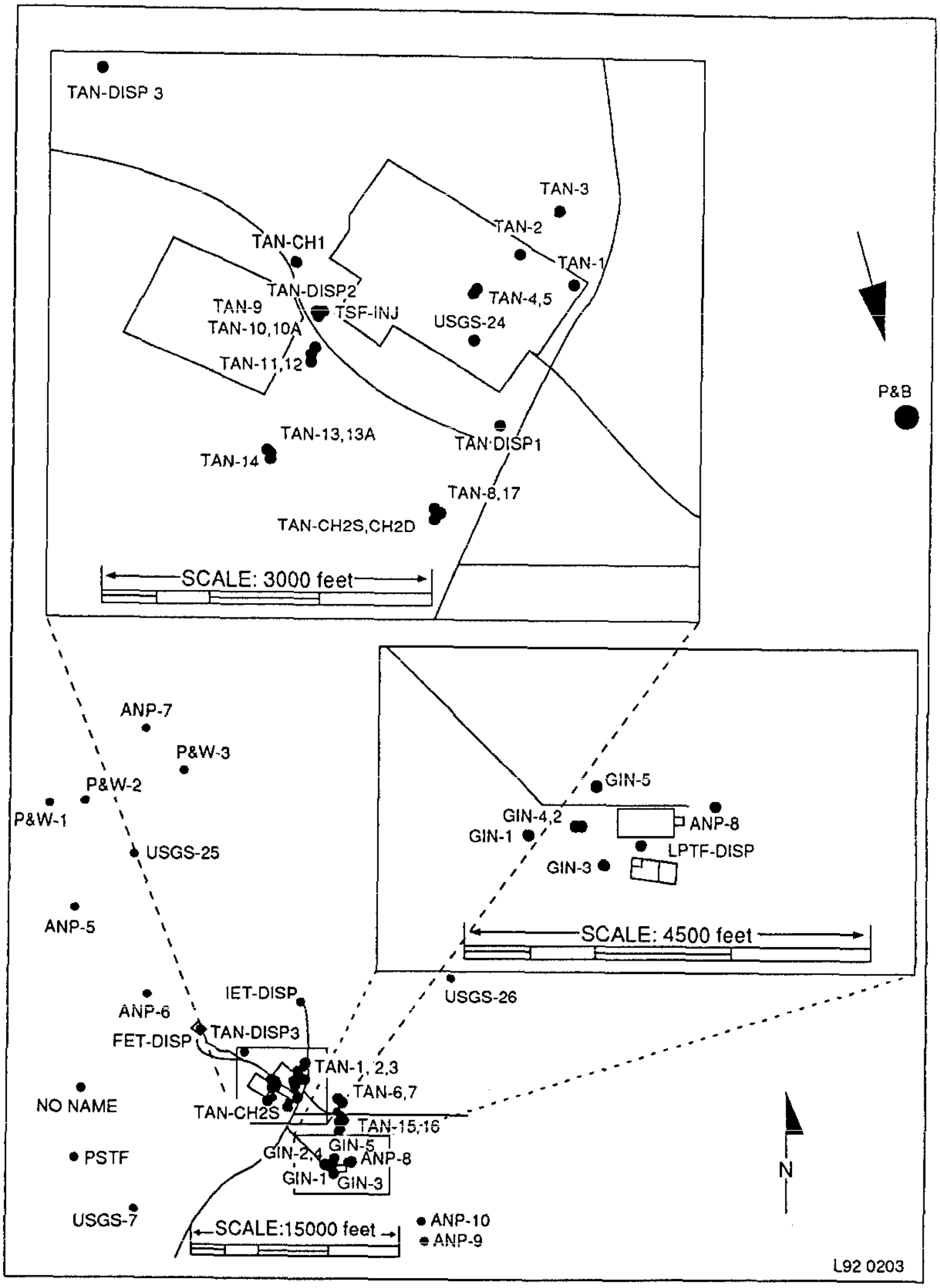


Figure H-2. Wells at TAN including the water supply wells (TAN-1 and TAN-2), injection wells (TAN-INJ, WRRTF-INJ, and IET-INJ), and other monitoring wells.

H-3. SUSPECTED MAJOR SOURCE OF CONTAMINANTS AT TAN

Major facilities at TAN include the Technical Support Facility (TSF), the Containment Test Facility (CTF), the Water Reactor Research Test Facility (WRRTF), and the Initial Engine Test (IET) Facility (see Figure H-1). TCE and PCE were found in the water supply wells (TAN-1 and TAN-2) for the TSF. On the basis of past disposal practices, historical records, personnel interviews, waste stream generation records, and contaminant monitoring/sampling, three disposal wells at TAN have been shown to be possible sources of TCE and/or PCE in the groundwater. These wells are shown in Figure H-2 and include the TSF, IET, and WRRTF injection wells. The primary source of contaminants is suspected to be the TSF injection well, based upon disposal history and measured contaminant levels. The IET and WRRTF injection wells are not reviewed here but are discussed in Sections 2.3.4, 2.3.5, and 2.4.2.3 of the Work Plan.

The TSF injection well was drilled to a depth of 305 ft to dispose of liquid effluent generated at TSF. The well has a 12-in. diameter casing to 305 ft and is perforated in two intervals, 180-244 ft and 269-305 ft below land surface (bls), respectively. The depth to groundwater is roughly 206 ft below land surface. Prior to 1972, the well was used as the primary disposal site at the TSF. Until the early 1980s, the well was also used for overflow from the sump at TAN-655. Discharges to the injection well included treated sanitary sewage, process waste waters, and low-level radioactive waste streams (see Section 2.3 of the Work Plan). The hazardous wastes include heavy metals, low-level radioactive nuclides, and unknown but potentially large quantities of organics.

H-4. GEOLOGY/LITHOLOGY OF THE AREA AT TAN

The TAN subsurface geology is characterized by basalt flows with sedimentary interbeds. Two of these interbeds have been correlated between wells beneath the water table and are illustrated in Figure H-3. These two clay/silt interbeds slope downward from the northwest to the southeast. The first of these beds (P-Q) intercepts the TSF injection well at a depth of approximately 225 ft bls. On the basis of monitoring in well pairs down-gradient of the TSF injection well (TAN-INJ), we suspect that either this shallow interbed is discontinuous and nonconfining, or that wastes were injected from both of the perforated intervals (above and below this interbed) in the injection well. It is unknown if the lower interbed (Q-R) is laterally continuous or confining.

If it is assumed that the Q-R interbed is laterally continuous, and acts as a confining layer, the thickness of the zone containing the injected contaminants varies. As shown in Figure H-3, the distance from the water table to the Q-R interbed varies from 100 ft in the northwest to 300 ft at the southeast corner of the TAN site. If the Q-R interbed is non-confining, the saturated thickness is much larger, ranging from 400-900 ft, with the upper 250 ft being the most permeable according to the United States Geological Survey (USGS) and a study by Robertson (1974).

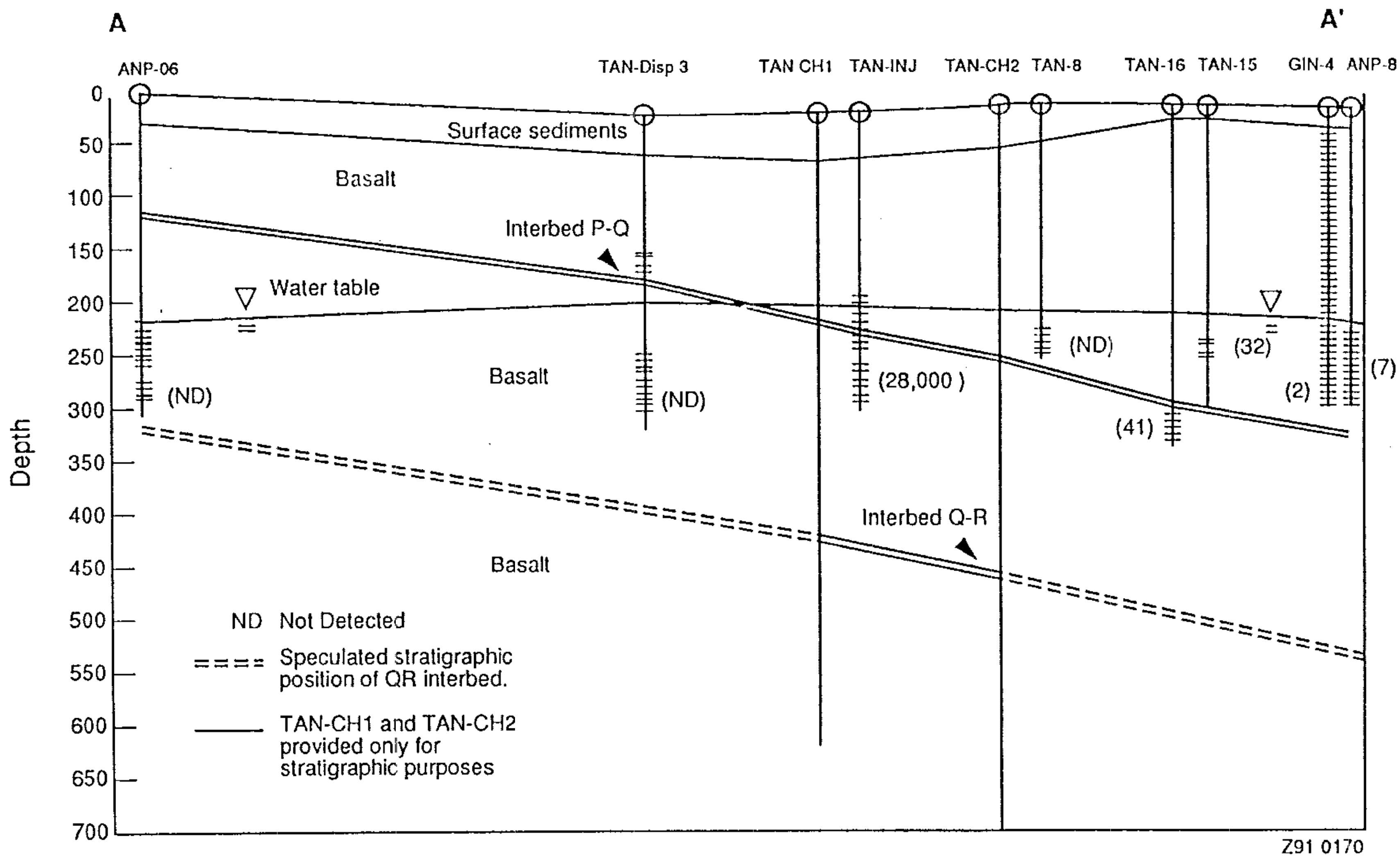


Figure H-3. Northwest-southeast cross sectional map showing interbeds, approximate water-table elevation, and well completion depths.

H-5. HYDROLOGY OF THE AREA AT TAN

Figure H-3 suggests that the basalts above and below the P-Q interbed are homogeneous and anisotropic. Field tests of the hydraulic properties and other geologic descriptions from wells in these basalts indicate otherwise. In general, the basalts beneath TAN are highly fractured both horizontally and vertically (Nace et al., 1956). The net effect of this heterogeneity creates a macroporosity system in which it is hypothesized that the large blocks of basalt (on the order of feet in diameter) act like the small grains of sand in a sedimentary system. Flow through the aquifer would follow a locally sinuous path around, through and between the large particles, in the general direction of the regional hydraulic gradient.

Pumping test results differ significantly from local slug test results. This variation is expectedly due to differences in area tested by each method (ft vs hundreds of ft). In addition, the slug test measures primarily horizontal permeability, while the pumping test incorporates some measure of vertical properties in cases where the completion intervals in the pumping and observation wells differ.

In addition to the permeability, porosity, and storativity data that have been collected at the TAN site (see Table H-1), water levels have been measured. These measurements indicate the position or elevation of the water table as a function of time. Figure H-4 shows water levels versus time (hydrographs) for several wells on the perimeter of the TAN area. Note that ANP7, USGS-7, OWSLEY-2, and Park & Bell (P&B) are located in the northwest, southwest, southeast, and northeast regions around TAN, respectively, while the USGS-24 well is located centrally with respect to site facilities.

The hydrographs indicate two levels of head fluctuations. The first level occurs on the order of tens of years, while the second is on an annual cycle (see Table H-2).

Table H-1. Storativity, transmissivity and perforated thickness at several TAN wells.

Well Name	Storativity	Transmissivity[a] (ft^2/day)	Perforated Thickness (ft)	Method[b] (P=Pump) (S=Slug)	Data[c] Source
ANP-5		1.5×10^5	78.0	P	A
ANP-6		5.0×10^5	75.0	P	A
ANP-9		6.6×10^3	100.0	P	A
FET-1		3.1×10^4	100.0	P	A
FET-2		1.1×10^4	239.0	P	A
FET-disp		1.5×10^4	120.0	P	A
IET-DISP		1.6×10^2	100.0	P	A
LPTF		3.5×10^3	119.0	P	A
P&W-1		2.5×10^5	50.0	P	A
P&W-2		1.4×10^5	68.0	P	A
P&W-3		1.4×10^4	79.0	P	A
PSTF		5.9×10^3	119.0	P	A
TAN-1	0.01	2.9×10^4	155.0	P	A
TAN-2	0.01	1.6×10^4	100.0	P	A
TAN-3		7.4×10^3	40.7	S	RIFS
TAN-4		7.5×10^2	25.0	S	RIFS
TAN-5		1.2×10^4	34.5	S	RIFS
TAN-6		4.0×10^2	28.5	S	RIFS
TAN-7		1.4×10^3	28.3	S	RIFS
TAN-8		2.6×10^2	25.5	S	RIFS
TAN-9		7.0×10^2	25.0	S	RIFS
TAN-10		2.0×10^4	40.0	S	RIFS
TAN-10A		1.2×10^3	38.2	S	RIFS
TAN-11		5.0×10^2	31.0	S	RIFS
TAN-12		9.5×10^1	25.6	S	RIFS
TAN-13A		5.0×10^2	35.5	S	RIFS
TAN-14		6.3×10^0	27.5	S	RIFS
TAN-15		1.7×10^3	27.1	S	RIFS
TAN-16		2.9×10^3	23.8	S	RIFS
TSF-INJ		3.0×10^1	100.0	P	A
USGS-24	0.003	1.4×10^4	70.0	P	A

a. Ackerman (1991) data were chosen over existing Wood (1989) data based on the use of partially penetrating vs fully penetrating well assumptions used in the analysis.

b. Slug tests were an average of Hvorslev (1951), Bouwer & Rice (1976), and Vanderkamp (1976) methods.

c. A=Ackerman (1991), W=Wood (1989), RIFS=TAN RI/FS Work Plan (EG&G Idaho 1992).

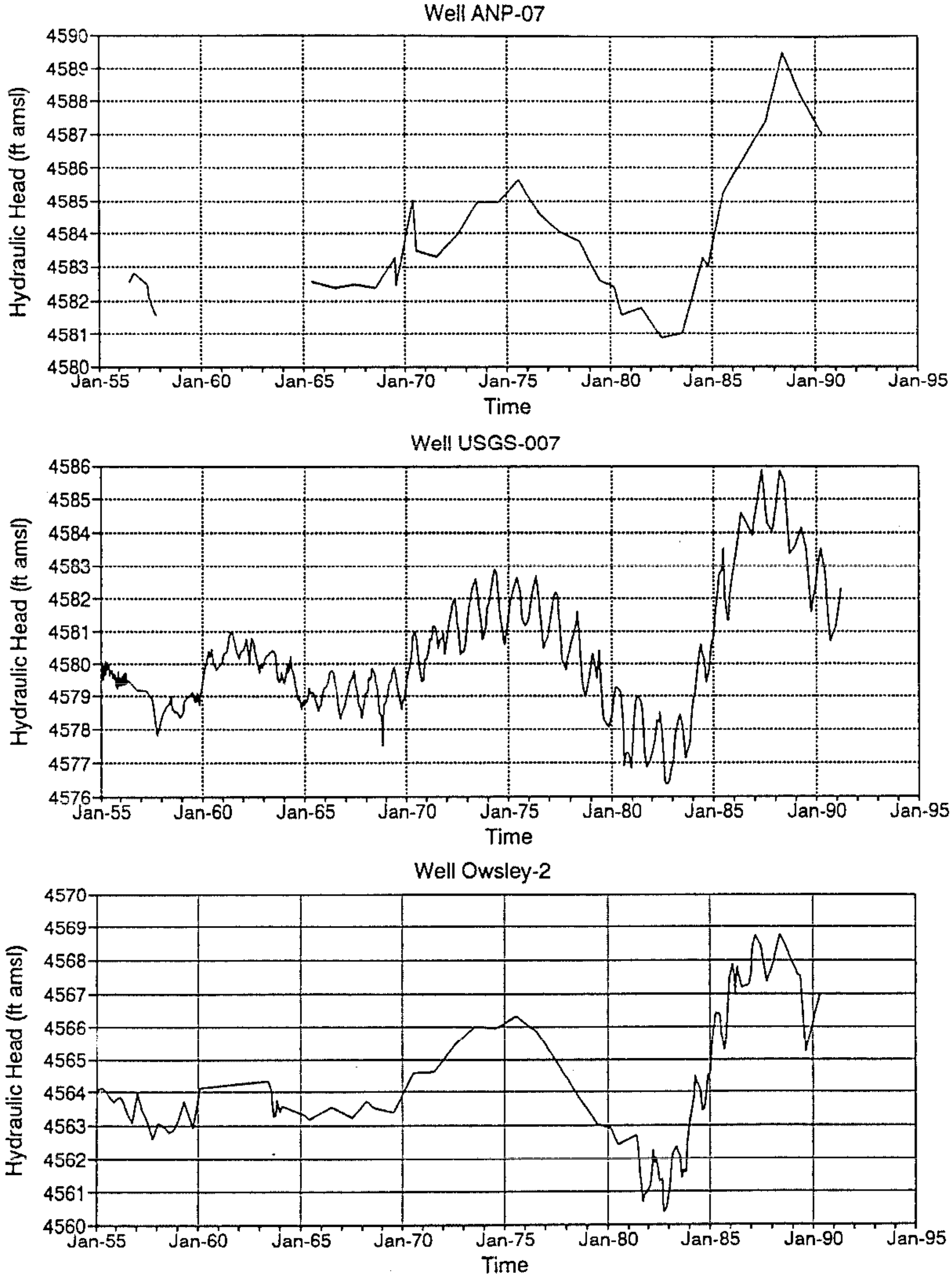
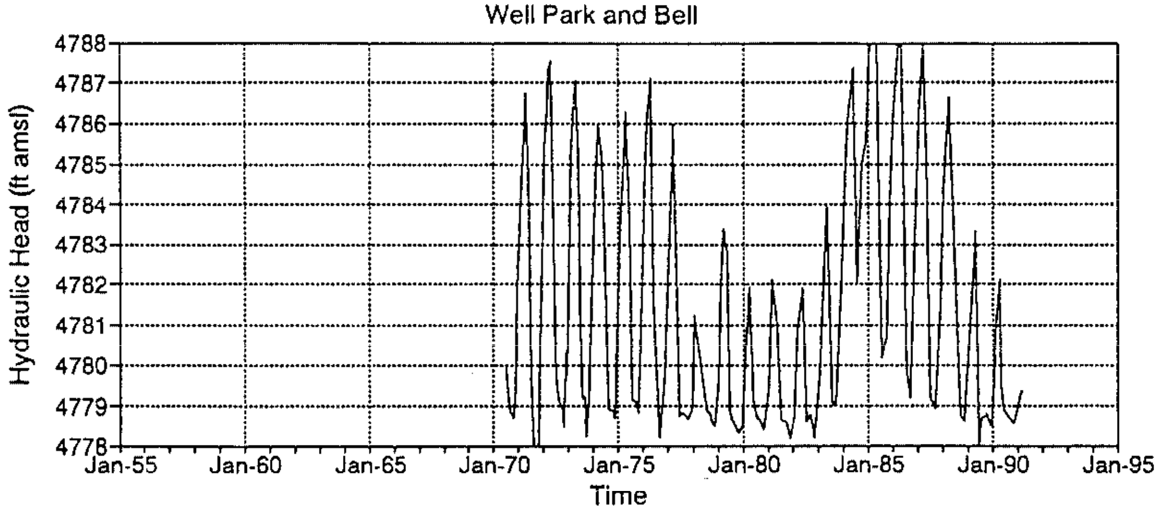


Figure H-4. Water levels versus time for ANP7, USGS-7, OWSLEY-2, Park & Bell, and USGS-24 wells.



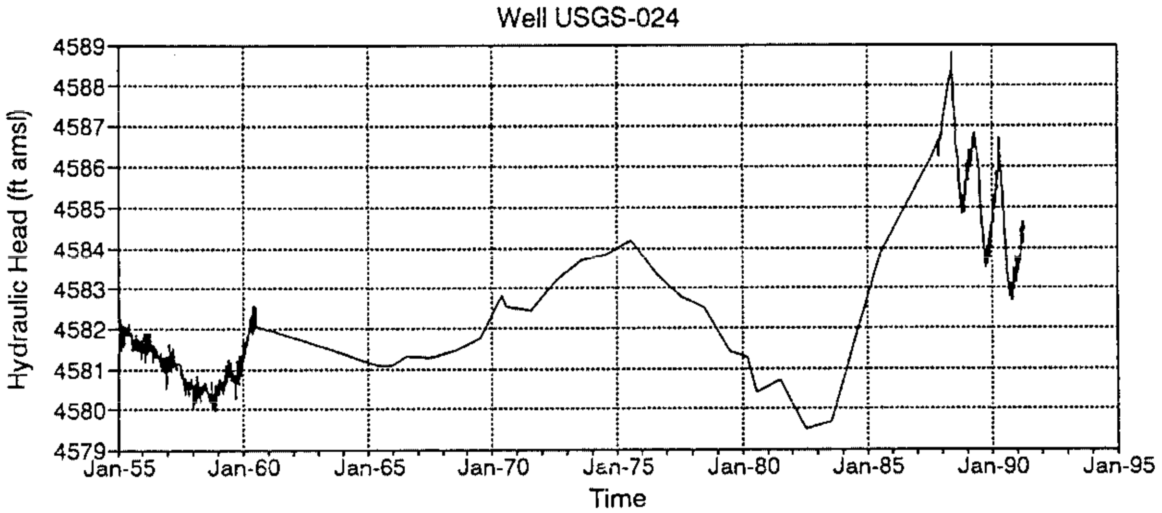


Figure H-4. (continued).

Table H-2. Summary of dominant hydrograph features for TAN wells.

Well Name	Comments
ANP7	Large time periodicity due to drought seasons
USGS-7	Large time periodicity due to drought seasons with small scale annual periodicity
OWSLEY-2	Large time periodicity due to drought seasons with small scale annual periodicity
P&B	Predominant small scale or annual periodicity
USGS-24	Large time periodicity due to drought seasons

The area of TAN adjacent to the recharge areas of Birch Creek and the Little Lost River experience large, long-term trends as opposed to the northeast areas (P&B) which experience annual cycles driven by local recharge and pumping.

Additional water-level measurements were taken in wells closer to TAN during the period from January 1980 to November 1991. These transient heads are presented for the 1990-1991 period in contoured form in Figure H-5.

Minimum, maximum, average, and standard deviations of the head measurements in the various wells are given in Table H-3. The first column gives the well name, while the second contains the number of head measurements taken between the beginning and ending dates. The absolute minimum head observed is shown in the fifth column and occurred at the date given in the sixth column. Similarly, maximum head information exists in the seventh and eighth positions. It is interesting to note that over a 10-year period, the standard deviation in head is on the order of 3 ft while changes of up to 20 ft were observed. These 10-year variations of heads on the order of 10 ft are significant in light of the small (0.002 ft/ft) regional gradient observed throughout the year. The data indicate that the overall water levels at TAN change significantly between dry and wet years. In addition, contoured head distributions indicate a strong dependence in the head near the TSF on local pumping rates in water supply wells TAN-1 and TAN-2.

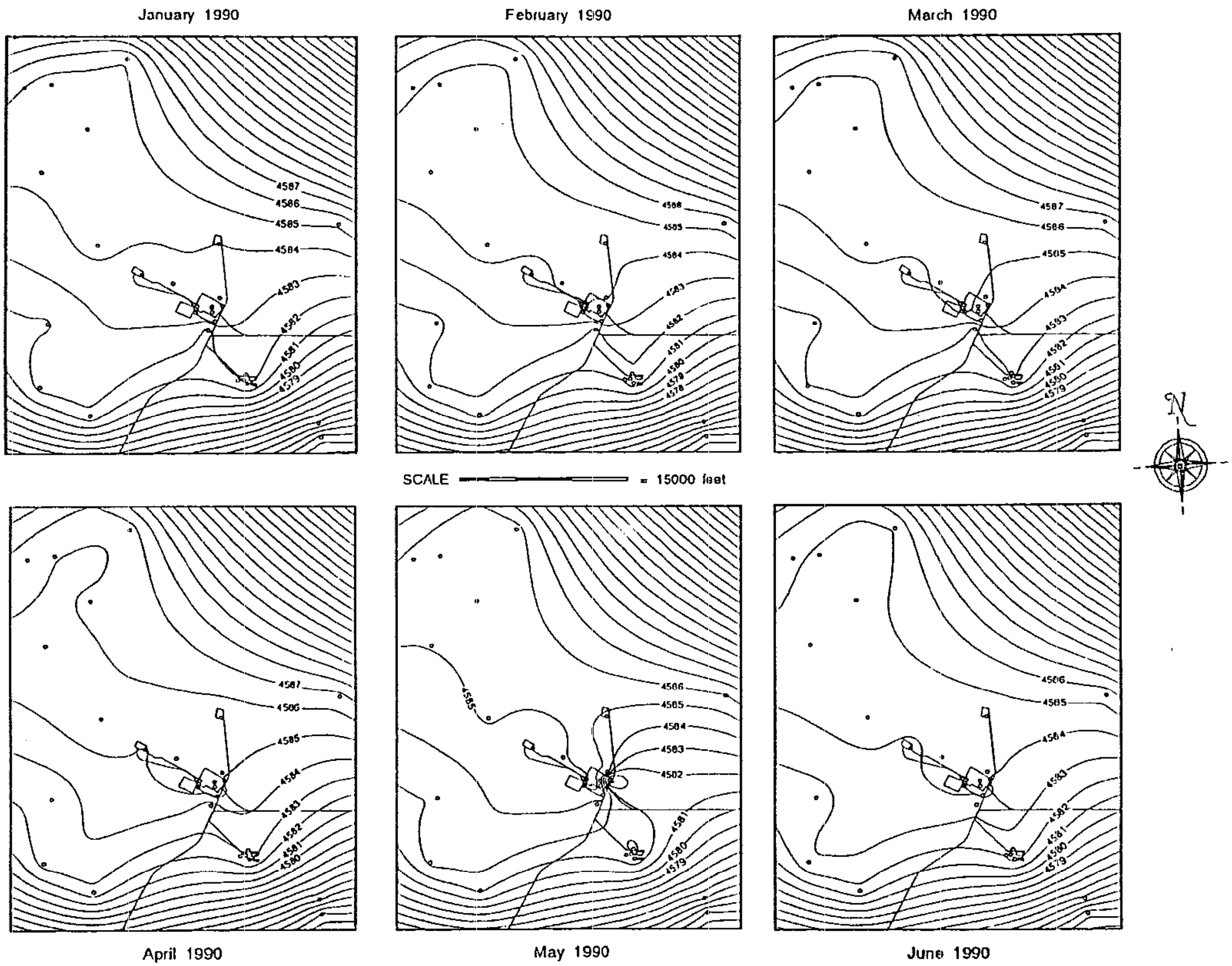


Figure H-5. Head measurements (contoured at an interval of ft) from January through September 1990, November through December 1990, and September 1991.

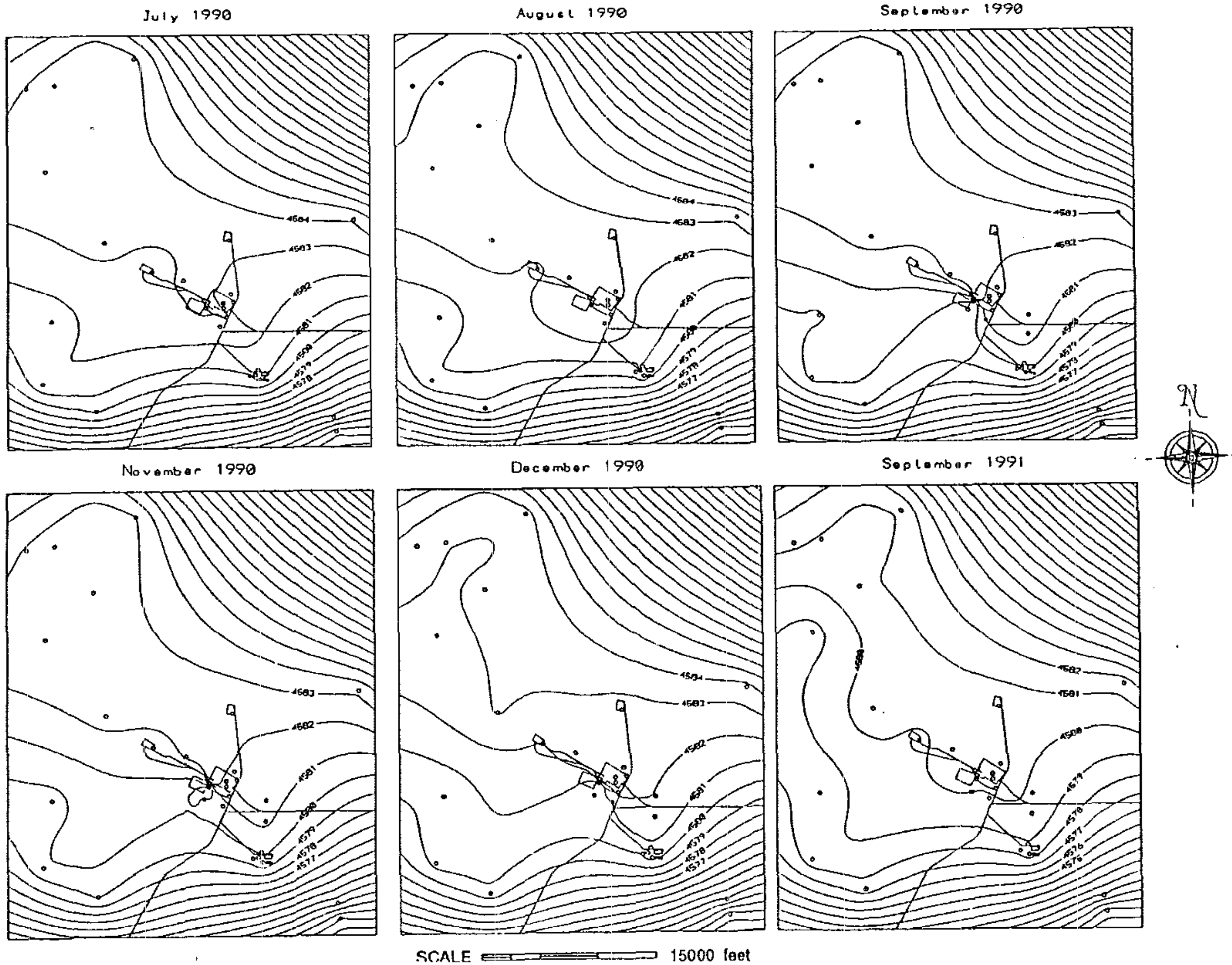


Figure H-5. (continued).

Table H-3. Variation in observed hydraulic head for TAN wells.

Well name	# of meas.	Begin Date	End Date	Minimum Head (ft)	Date@ Min H	Maximum Head (ft)	Date@ Max H	Average Head (ft)	S.D. of H	Change in H
ANP-5	26	Mar-80	Nov-91	4579.27	Jul-82	4588.08	Feb-87	4583.03	2.25	8.81
ANP-6	20	May-86	Oct-91	4580.30	Oct-91	4587.84	Mar-87	4584.17	1.91	7.54
ANP-7	25	Mar-80	Nov-91	4580.87	Jul-82	4589.56	Jan-86	4584.75	2.66	8.69
ANP-9	25	Feb-87	Nov-91	4565.70	Nov-91	4573.20	Jun-85	4569.94	2.00	7.50
ANP-10	23	Mar-80	Nov-91	4568.68	Jul-82	4574.30	May-89	4571.54	1.72	5.62
FET-DISP	20	Jul-84	Nov-91	4579.10	Nov-91	4586.83	Jan-87	4582.66	2.04	7.73
GIN-1	17	Jul-84	Nov-91	4577.10	Nov-91	4582.57	May-89	4580.29	1.62	5.47
GIN-2	23	Mar-80	Sep-90	4577.16	Jul-82	4585.56	Jun-87	4581.08	2.36	8.40
GIN-3	18	Jul-84	Nov-91	4577.50	Nov-91	4583.89	May-86	4580.86	1.76	6.39
GIN-4	14	Jul-84	Dec-90	4579.35	Jun-83	4582.99	Aug-89	4581.24	1.21	3.64
GIN-5	17	Jul-84	Nov-91	4577.90	Nov-91	4583.47	May-89	4581.07	1.66	5.57
IET-DIS:	28	Jul-80	Nov-91	4578.96	Jul-82	4587.50	Jan-87	4582.88	2.42	8.54
NO NAME	26	Mar-80	Nov-91	4576.90	Jul-82	4585.41	Feb-87	4580.42	2.45	8.51
OWSLEY-2	82	Mar-80	Nov-91	4560.37	Sep-82	4568.75	Jan-87	4564.13	2.38	8.38
P&B	155	Jun-70	Mar-91	4768.61	Sep-71	4790.04	May-85	4768.61	3.31	21.43
P&W-11	25	Mar-80	Nov-91	4579.65	Jul-82	4588.47	Feb-87	4583.24	2.34	8.82
P&W-2	40	Mar-80	Nov-91	4579.19	Jan-83	4588.03	Sep-86	4583.91	2.58	8.84
P&W-3	27	Mar-80	Nov-91	4579.48	Jul-82	4588.35	Dec-84	4583.50	2.54	8.87
PSTF	28	Mar-80	Nov-91	4565.22	May-88	4585.78	Dec-86	4579.70	4.40	20.56
TAN-1	16	Nov-87	Nov-91	4578.80	Nov-91	4585.20	Aug-86	4582.08	2.00	6.40
TAN-2	1	Nov-87	Nov-87	4572.72	Nov-87	4572.72	Nov-87	4572.72	0.00	0.00
TAN-3	15	Jan-90	Nov-91	4579.40	Nov-91	4585.13	May-89	4582.59	1.74	5.73
TAN-4	15	Jan-90	Nov-91	4579.20	Nov-91	4585.19	May-89	4582.57	1.73	5.99
TAN-5	15	Jan-90	Nov-91	4580.09	Sep-91	4585.12	May-89	4582.65	1.49	5.03
TAN-6	7	Sep-90	Nov-91	4579.20	Nov-91	4581.97	Sep-90	4580.76	0.98	2.77
TAN-7	7	Sep-90	Nov-91	4579.20	Nov-91	4581.96	Sep-90	4580.70	0.96	2.76
TAN-8	15	Jan-90	Nov-91	4578.50	Nov-91	4583.36	Jul-89	4581.43	1.46	4.86
TAN-9	15	Jan-90	Nov-91	4579.80	Nov-91	4585.67	May-89	4583.03	1.70	5.87
TAN-10	15	Jan-90	Nov-91	4579.70	Nov-91	4585.54	May-89	4582.92	1.82	5.84
TAN-10A	12	Apr-90	Nov-91	4580.00	Nov-91	4585.84	May-89	4582.84	1.74	5.84
TAN-11	15	Jan-90	Nov-91	4579.70	Nov-91	4585.58	May-89	4582.92	1.73	5.88
TAN-12	7	Sep-90	Nov-91	4574.90	Nov-91	4577.86	Sep-90	4576.60	1.06	2.96
TAN-13	1	Oct-90	Oct-90	4580.54	Oct-90	4580.54	Oct-90	4580.54	0.00	0.00
TAN-13A	5	Nov-90	Nov-91	4578.80	Nov-91	4580.83	Sep-90	4579.64	0.71	2.03
TAN-14	6	Oct-90	Nov-91	4578.60	Nov-91	4580.82	Jul-90	4579.81	0.91	2.22
TAN-15	6	Sep-90	Nov-91	4578.70	Nov-91	4581.71	Sep-90	4580.29	1.11	3.01
TAN-16	7	Sep-90	Nov-91	4578.80	Nov-91	4581.77	Sep-90	4580.48	1.07	2.97
TAN-CH1	15	Jan-90	Nov-91	4579.60	Nov-91	4585.56	May-89	4582.73	1.78	5.96
TAN-CH2S	4	Dec-90	Nov-91	4587.90	Nov-91	4591.92	Sep-90	4589.04	1.67	4.02
TAN-CH2D	5	Nov-90	Nov-91	4576.90	Nov-91	4579.68	Sep-90	4577.99	1.05	2.78
TAN-D1	15	Jan-90	Nov-91	4579.40	Nov-91	4585.35	May-89	4582.70	1.75	5.95
TAN-D2	15	Jan-90	Nov-91	4579.70	Nov-91	4585.59	May-89	4582.94	1.72	5.89
TAN-D3	15	Jan-90	Nov-91	4580.20	Nov-91	4585.60	May-89	4582.95	1.69	5.40
USGS-7	93	Jan-80	Nov-91	4575.10	Sep-82	4584.60	Aug-85	4578.73	2.49	9.50
USGS-24	46	Mar-80	Nov-91	4578.54	Jul-82	4587.43	Jul-85	4583.45	2.24	8.89
USGS-25	130	Jan-80	Nov-91	4578.09	Sep-82	4588.52	May-85	4582.95	2.89	10.43
USGS-26	99	Jan-80	Nov-91	4578.71	Aug-82	4589.03	Apr-86	4582.74	2.71	10.32

Pumping rates for the two supply wells are given in Table H-4. Large drawdowns or decreases in heads near the TSF correspond to periods of high pumping. The combination of pumping, annual recharge, and long-term changes in recharge contribute to the highly dynamic water-table elevations observed at TAN. However, the variation in head (10 ft) caused by pumping is relatively small in comparison with the total thickness of the aquifer (>400 ft), which suggests that changes in head caused by pumping events occur near the top of the water table, and do not create larger vertical flow components at depth.

To examine the hypothesis that in addition to horizontal dynamics, vertical flow components within the aquifer exist, water levels have been measured in nested well pairs. There are several wells that are separated by short horizontal distances in which water levels have been taken at different elevations. Head data at a single point in time for these nested well pairs are given in Table H-5.

At first glance, there appears to be a large component of vertical flow relative to the horizontal gradient. We feel that these numbers are misleading for three main reasons:

1. The horizontal separation of wells is on the same order as the vertical separation in all but one well. This means that the measurements reflect as much horizontal flow potential as vertical.

2. Ideally, gradients should be measured at two points along the same flow path (i.e., vertical). In fractured basalts, there is no guarantee that the well pairs are connected by the same set of fractures or matrix blocks.

3. If the vertical flow gradients were actual instead of illusory, contaminants injected at the TAN-INJ well would travel at a rate of

   $$v_z = \frac{k}{\phi}\frac{dh}{dz} \approx \frac{100(\text{ft/day})}{0.1} \times 3.5\text{E-}03(\text{ft/ft}) \approx 3.5 \text{ ft/day}$$

   vertically, which when coupled with a similar horizontal velocity results in an approximately forty-five degree downward movement. This net downward velocity would cause the injected contaminants to travel from the upper 400-ft thickness of the aquifer within a year of having been introduced. Instead, we measure significant concentrations of injected organics several thousands of feet horizontally from the TAN-INJ well.

Table H-4. Monthly water volume and volumetric rates for TAN water supply wells.

Date	TAN-1 Volume (10^3 gal)	TAN-2 Volume (10^3 gal)	Total Volume Withdrawn (10^3 gal)	Average Combined Withdrawal Rate (gal/day)
Jan-90	804	1255	2059	66423
Feb-90	1084	640	1723	61553
Mar-90	1606	74	1680	54209
Apr-90	1237	132	1369	45646
May-90	2391	70	2461	79403
June-90	1596	15	1611	53685
July-90	2855	14	2870	92570
Aug-90	2557	464	3020	97430
Sep-90	33	2775	2808	93606
Oct-90	1106	891	1997	64414
Nov-90	1980	130	2110	70343
Dec-90	1666	14	1680	54183
Jan-91	4724	14	4738	152830
Feb-91	1841	0	1841	65737
Mar-91	1854	0	1854	59801
Apr-91	2093	0	2093	69780
May-91	1705	409	2114	68193

Table H-5. Horizontal and vertical hydraulic head gradients.

Well Pairs	Date	Horizontal Well Separation (ft)	Vertical Well Separation (ft)	Head Difference (ft)	Vertical Gradient (ft/ft)	Horizontal Gradient (ft/ft)
TAN-4 - TAN-5	Sep-90	43.01	63.00	0.07	1.12E-03	1.63E-03
TAN-6 - TAN-7	Sep-90	47.17	12.30	0.02	1.63E-03	4.24E-04
TAN-13A - TAN-14	Nov-90	63.16	60.00	1.60	2.67E-02	2.53E-02
TAN-10A - TAN-11	Sep-90	79.40	66.80	0.26	3.90E-03	3.28E-03
TAN-11 - TAN-12	Sep-90	44.94	72.00	4.81	6.68E-02	1.07E-01
TAN-10A - TAN-12	Sep-90	118.09	139.00	5.07	3.65E-02	4.29E-02
TAN-15 - TAN-16	Sep-90	45.01	70.00	0.18	2.57E-03	3.99E-03
TAN-CH2S - TAN-CH2D	Dec-90	0.00	583.00	12.24	2.10E-02	

After relating these apparent vertical gradients to measured values of concentration obtained over large horizontal distances, it is apparent that although there may be some vertical movement of contaminants, the net movement is horizontal.

There is, however, one important geological feature that stands out when examining the vertical distribution of heads, namely the apparently upward vertical gradient from the shallow perforated interval of the TAN-CH2 well to the other wells in the vicinity of TAN-CH2S. For example, the head in TAN-CH2S is about 10 ft higher than the head in TAN-8, which results in an apparent upward gradient of 0.04 ft/ft. The macroporous media model, which suggests that the total flow path consists of a combination of small vertical and larger horizontal movements around and through the large basalt blocks, with a net horizontal movement, cannot be used to explain this observation. It can be explained by examining Figure H-3, which illustrates the penetration depth of TAN-CH2. Note that the completion elevation interval of TAN-CH2 is between 4,311.2 and 4,299.42 ft, approximately 200 ft below the Q-R interbed. A classical three-point analysis using the TAN-CH2, TAN-CH1, and USGS-7 wells can be used to project the Q-R interbed northward from the immediate vicinity of TAN where it subcrops the water table at an elevation of about 4,600 ft (see Section 2.1.6.6 of the Work Plan).

The working hypothesis is that TAN-CH2 is in communication with those higher-upgradient heads, and that the Q-R interbed is effectively confining between the subcrop area and TAN-CH2. Section 2.1.6.6 further suggests and discounts the four following hypotheses based on conceptually feasible but improbable hydraulics: (1) a completely plugged well, (2) a remnant head from the 1969 flood, (3) a residual head from the injection well, and (4) a lowered head above the Q-R as a result of pumping from the TAN-1,2 wells. The hydraulic arguments against the four hypothesis are respectively:

1. For TAN-CH2 to act as a plugged well, it would have to have been completed in completely impermeable sediments in which the higher head incurred during drilling was trapped. A 12-ft impermeable interval is unlikely to occur in the fractured basalts existing at the INEL, but the possibility will be investigated using a simple slug test.

2-3. A residual head from either the flood of 1969, or from injection activities that ceased 20 years ago is improbable based on the storativity of basalts (0.001-0.01). In addition, we note that either of these possibilities would require the storing and gradual release of an equivalent flux of 7 million gallons of water per day.

4. It is possible that pumping at TAN-1,2 has lowered the head above the Q-R interbed in the shallow wells; however, 96% of the pumped water is returned to the aquifer via infiltration ponds.

After examining the possible scenarios, it is most likely that the Q-R interbed allows the TAN-CH2S interval to communicate with higher upgradient heads. This communication effectively defines the bottom of the upper-aquifer system.

Although we measure local components of vertical flow within the upper-aquifer, the primary flow direction appears to be horizontal. The most plausible explanation for this discrepancy goes back to the macroporosity view of the fractured basalt system, where again we hypothesize that the total flow path consists of a combination of vertical and horizontal movements, resulting in large net horizontal movements with a large vertical mixing zone. This hypothesis is substantiated by the concentrations of contaminants measured through a large vertical and horizontal section of the aquifer. Substantiating data are presented below in the form of similar concentration values measured in both wells of a vertically nested well pair (TAN-4 and TAN-5).

The concentration of TCE, PCE, ^{90}Sr, and ^{3}H were measured in the TAN groundwater. Contour plots of these concentration measurements are summarized in Table H-6 and are shown in Figure H-6.

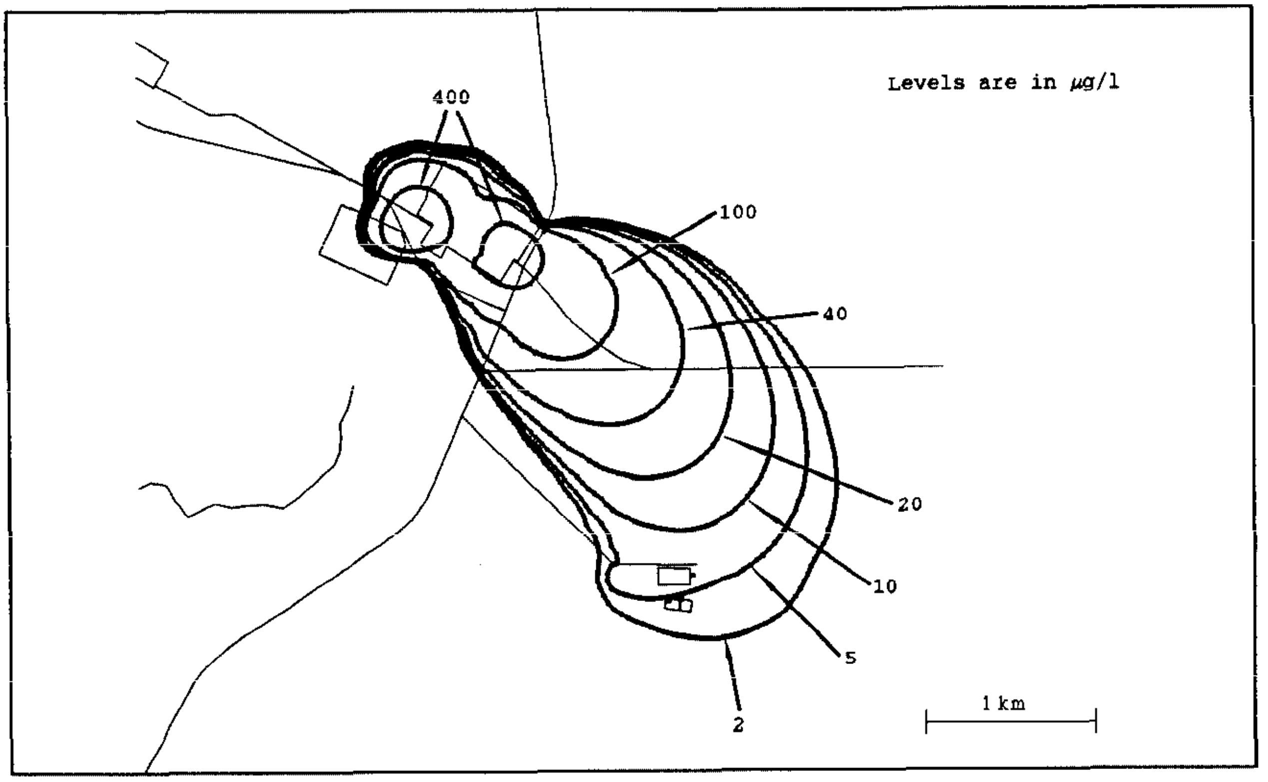
The concentration contour plots indicate a generally southeastern movement consistent with the regional groundwater flow direction. However, we believe that the pumping wells at the TSF tend to draw the plume further to the north near the TAN-1 and TAN-2 wells, resulting in a delayed movement to the southeast and a larger spreading thickness than would result from regional (ambient) groundwater movement alone. These concentration values support our assumption of vertical mixing of contaminants that results in net horizontal movement of a large thickness.

Table H-6. December 1989 well concentrations.

Well Name	TCE ($\mu g/L$)	PCE ($\mu g/L$)	^{90}Sr (pCi/L)	^{3}H (pCi/mL)
ANP-6	ND	ND	2 ± 2	ND
ANP-8	6	1	2 ± 2	ND
TAN-1	7	2	10 ± 2	ND
TAN-3	ND	ND	4 ±2	ND
TAN-4	70	20	2 ± 2	0.9 ± 0.2
TAN-5	71	16	ND	1.7 ± 0.4
TAN-8	ND	ND	3 ± 2	ND
TAN-9	86	17	15 ± 3	8. ± 0.6
TAN-10	28	11	76 ± 7	2.8 ± 0.3
TAN-11	89	24	6 ± 2	3.5 ± 0.6
TAN-D1	150	23	ND	2. ± 0.4
TAN-D2	660	11	230 ± 20	4.4 ± 0.7
USGS-24	1300	71	ND	9.8 ± 0.7
USGS-26	ND	ND	2 ± 2	ND
TSF-INJ[a]	28000	37	200	20.9 ± 2.7[b]

a. March 1989 concentration measurements.

b. March 1989 value reduced 4% from 21.8 (radioactive decay).



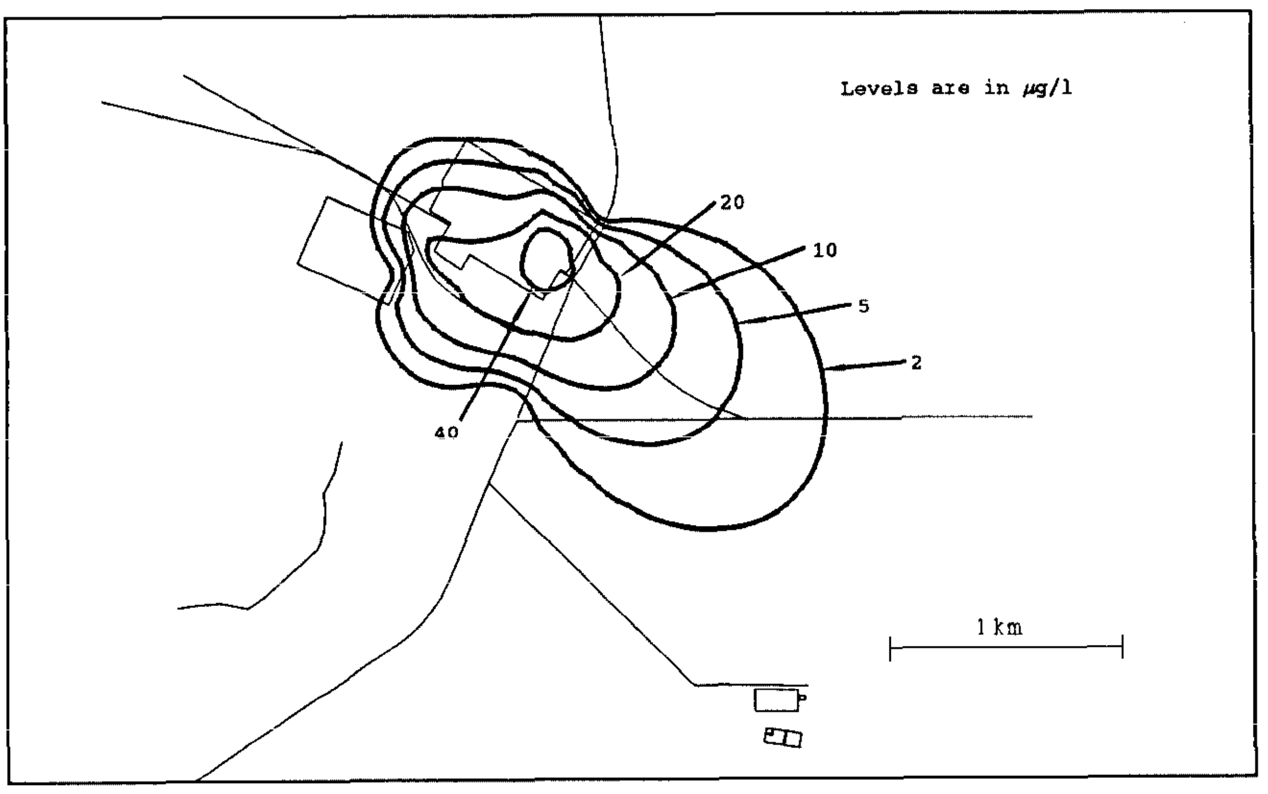
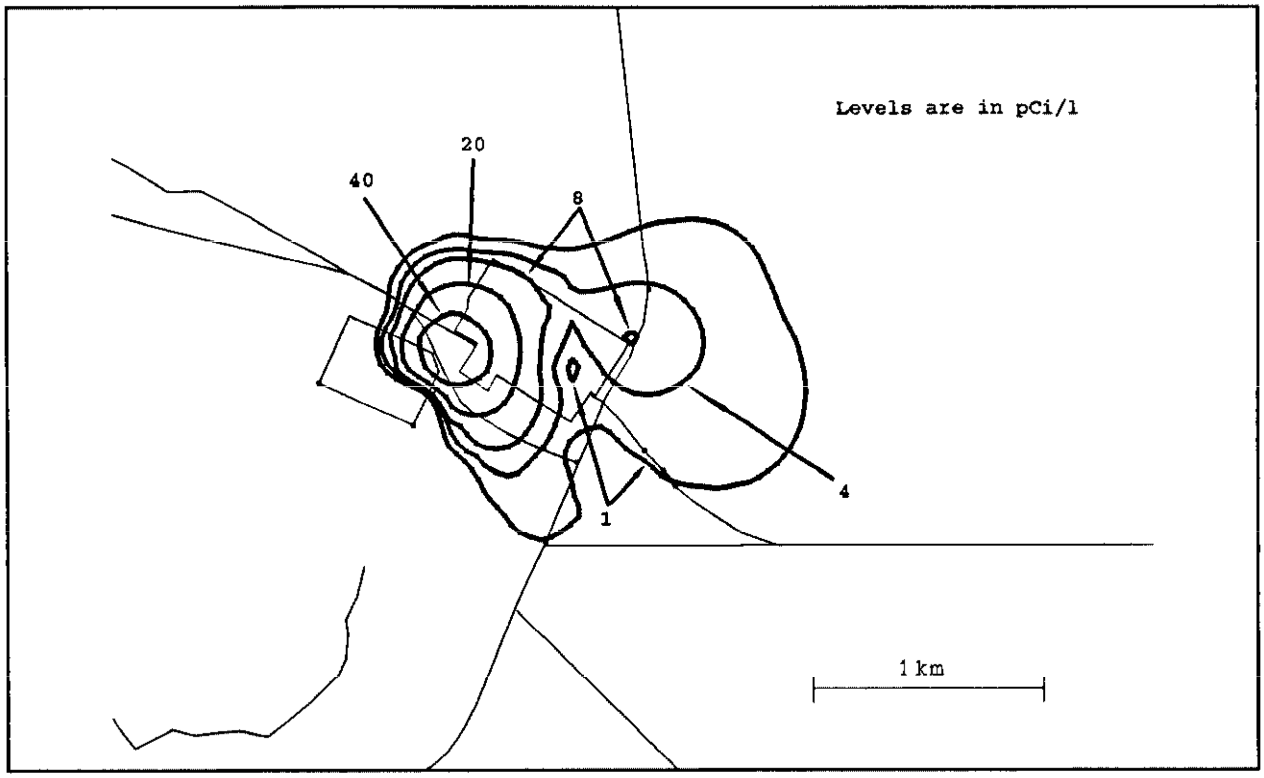


Figure H-6. Concentration contours of TCE, PCE, ^{90}Sr, and ^{3}H measured in the TAN groundwater.



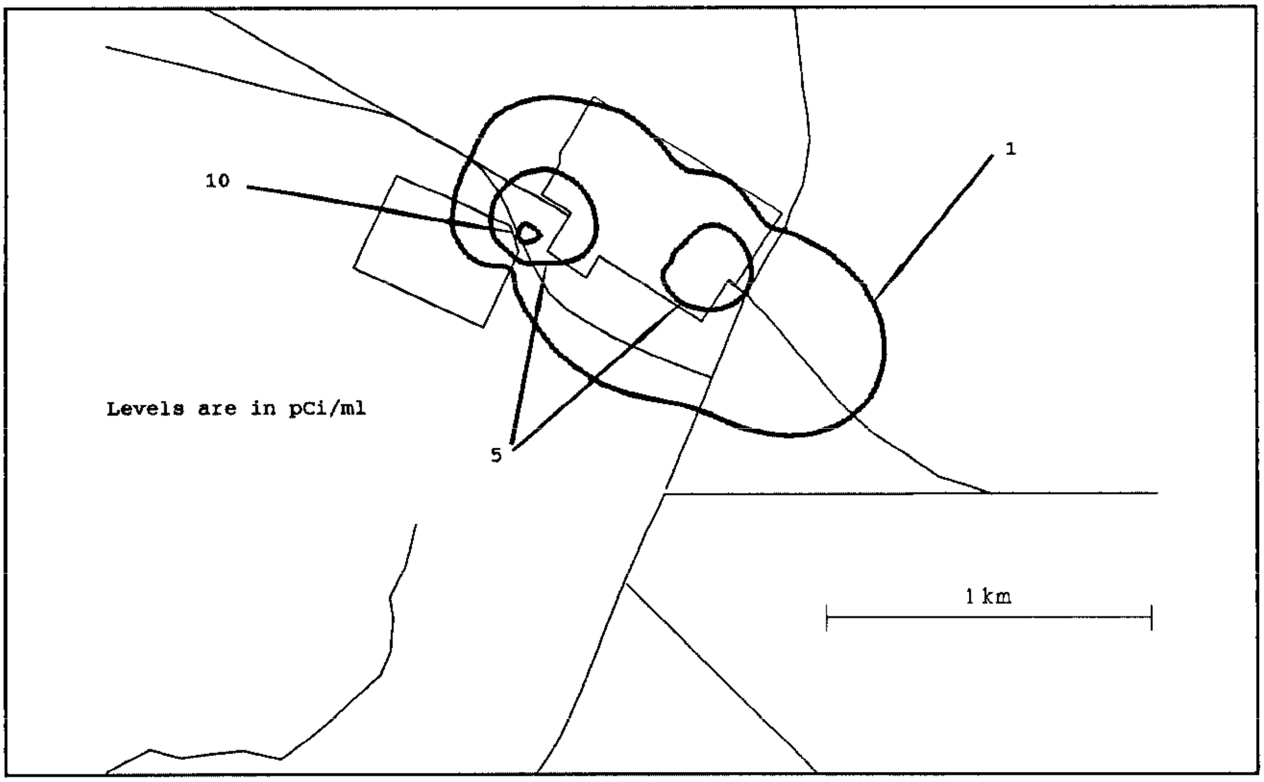


Figure H-6. (continued).

H-6. PREVIOUS MODELING STUDY

As a first approximation, the groundwater flow and transport system was numerically simulated in a study ending in June 1990 (EG&G Idaho, 1990). The approach taken assumed a steady-state head distribution at the TAN site. The modeling approach neglected the recharge occurring at the terminus of Birch Creek and Little Lost River, and the effects of pumping from the water supply wells and recharge in the disposal ponds.

The study assumed that the heads of January 1990 were representative of a one-hundred year average condition. By adjusting transmissivity values, a reasonable match of the hydraulic heads was achieved (see Figure H-7). Using the steady-state head configuration, concentration distributions of TCE, PCE, ^{90}Sr, and ^{3}H were predicted over a time period of 40 years (see Figure H-8).

Examination of the computed concentration plumes with known regional groundwater gradients, and the spatial distribution of contaminants on January 1990 illustrates the following differences between simulated results and expected values, which are easily explained by the modeling approach:

1. There is a significant difference in plume orientation between the modeling results and current measurements.
2. The simulated plume is much narrower than expected, which highlights the faults of that preliminary modeling study.

Groundwater flow directions and directions of contaminant movement are dictated by the hydraulic head gradients. As shown by the data presented in Figures H-4 and H-5, the head distribution at TAN is very dynamic. The arbitrarily selected January 1990 heads are probably not representative of long-term head gradients existing at the site. In addition, the chosen head distribution was not subject to long-term changes caused by periodically wetter/dryer years, or to changes in local groundwater heads caused by changes in pumping rates from the water supply wells.

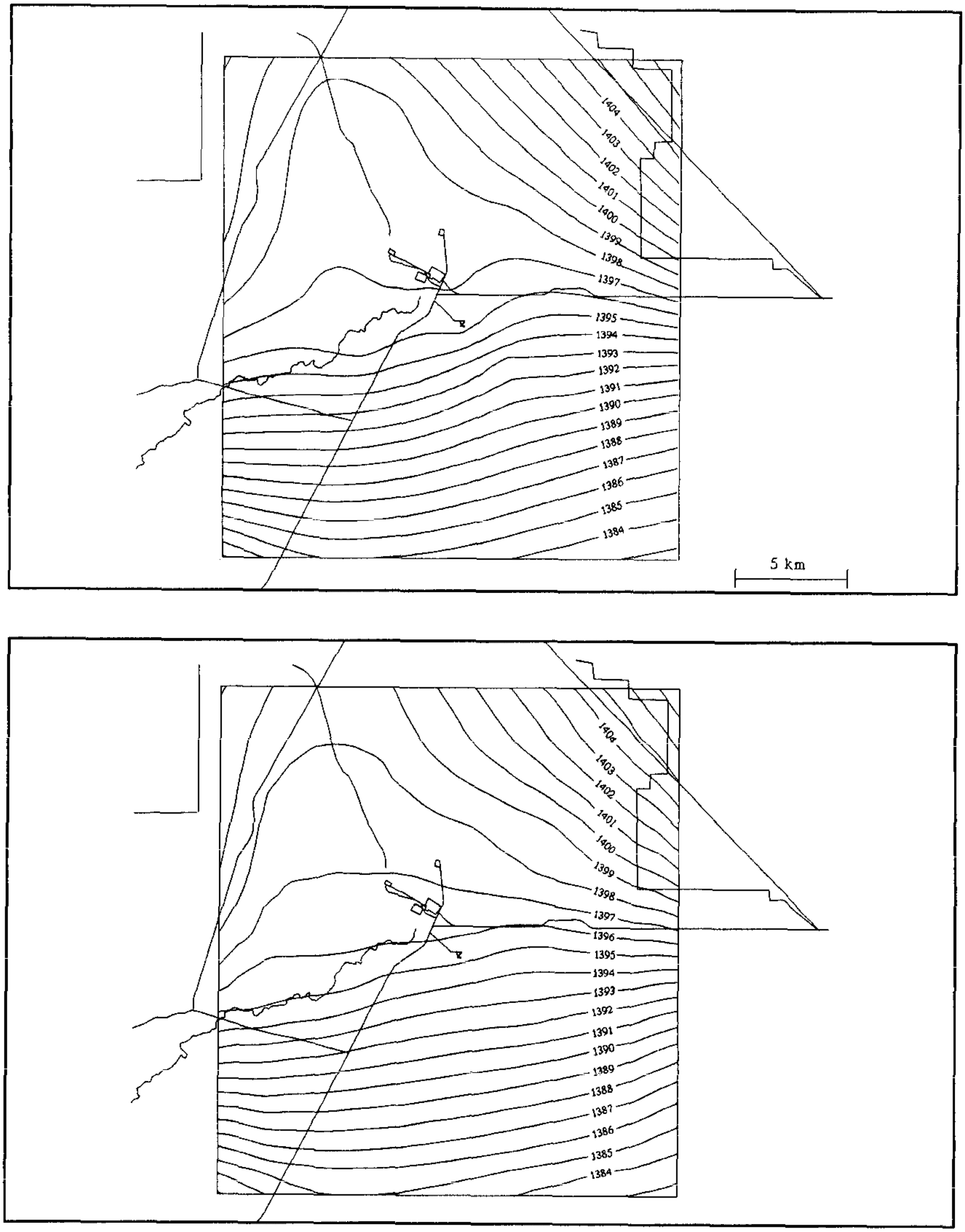


Figure H-7. Hydraulic heads of January 1990 from field data, and the same data simulated by adjusting transmissivity values.

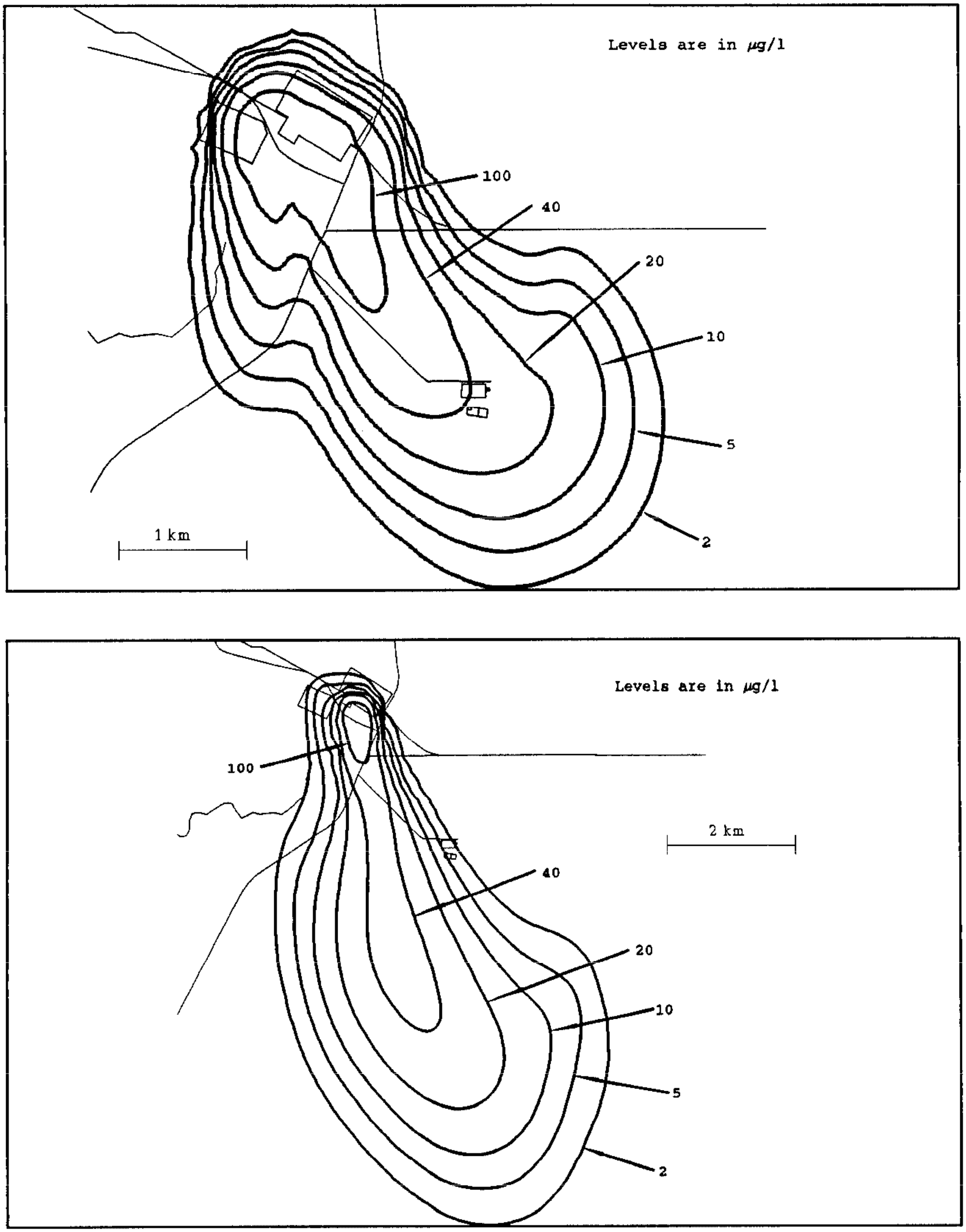
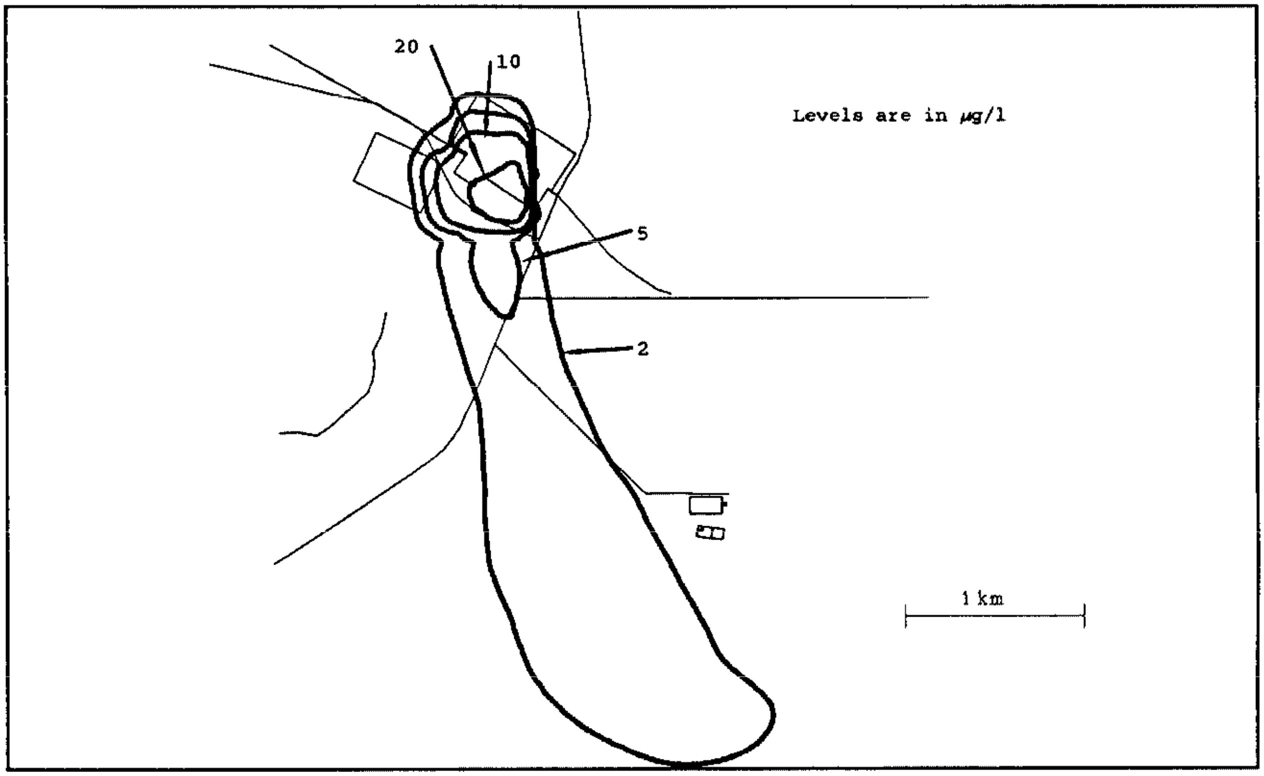


Figure H-8a. Concentration contours of TCE for the years 2000 and 2030, simulated using steady-state heads of January 1990.



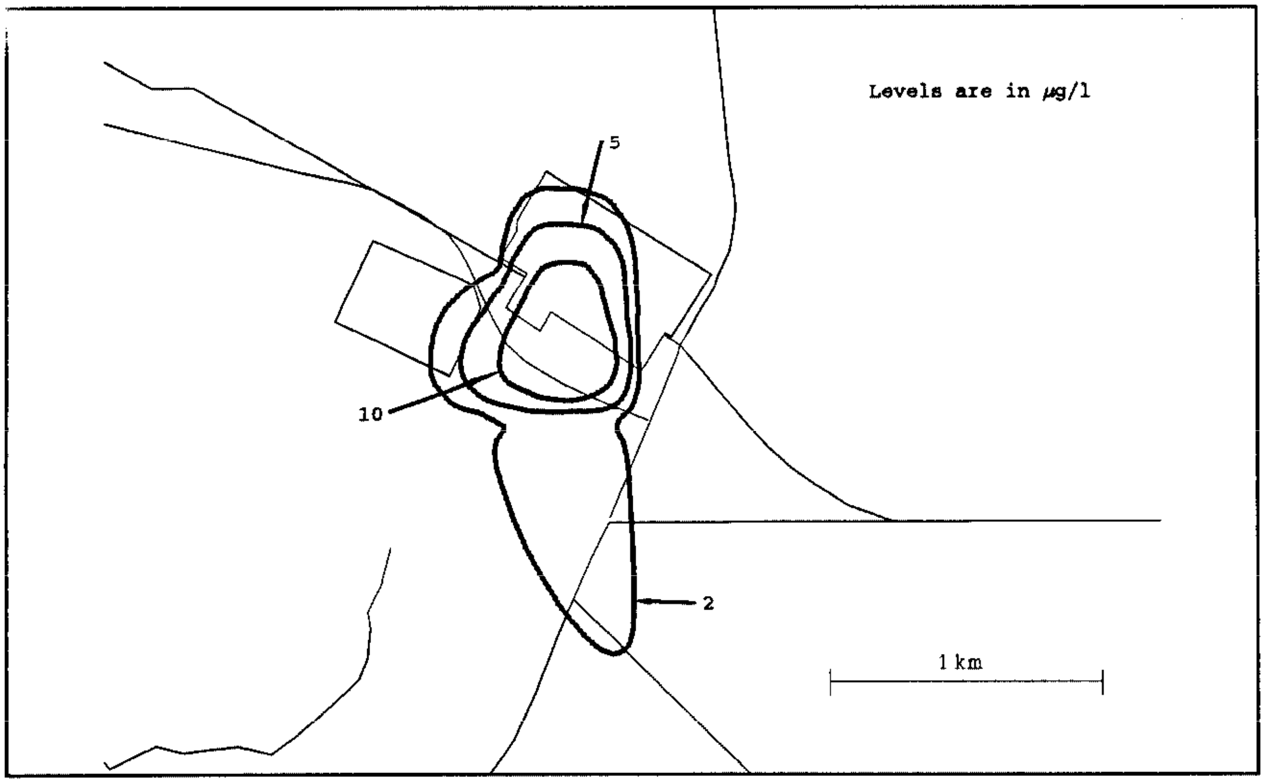
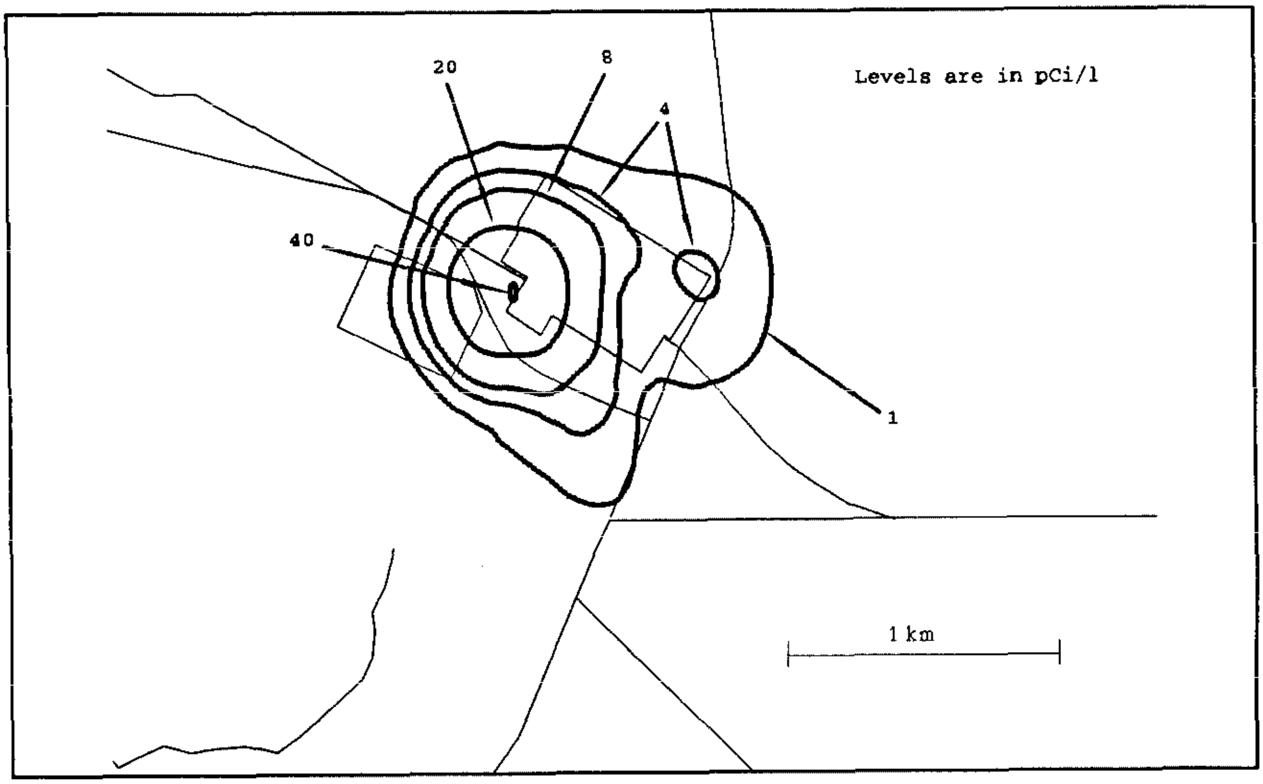


Figure H-8b. Concentration contours of PCE for the years 2000 and 2030, simulated using steady-state heads of January 1990.



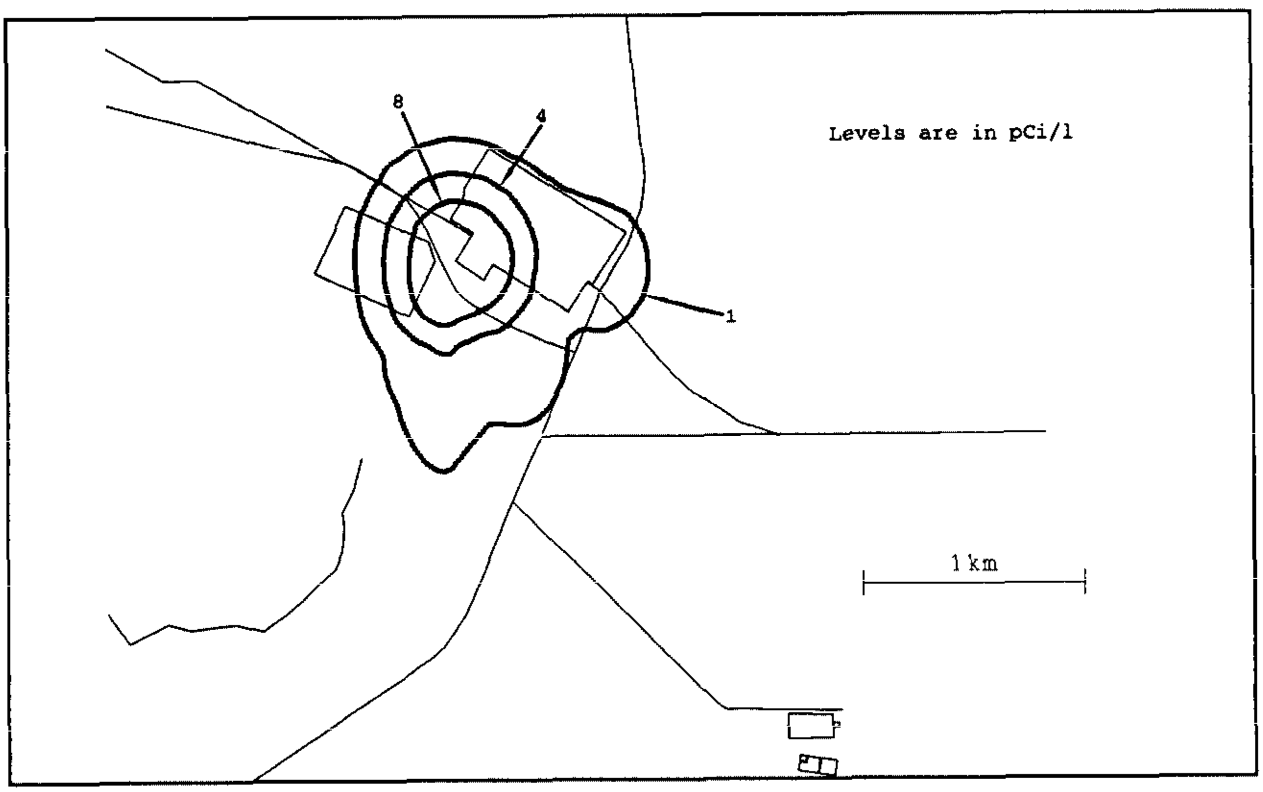


Figure H-8c. Concentration contours of ^{90}Sr for the years 2000 and 2030, simulated using steady-state heads of January 1990.

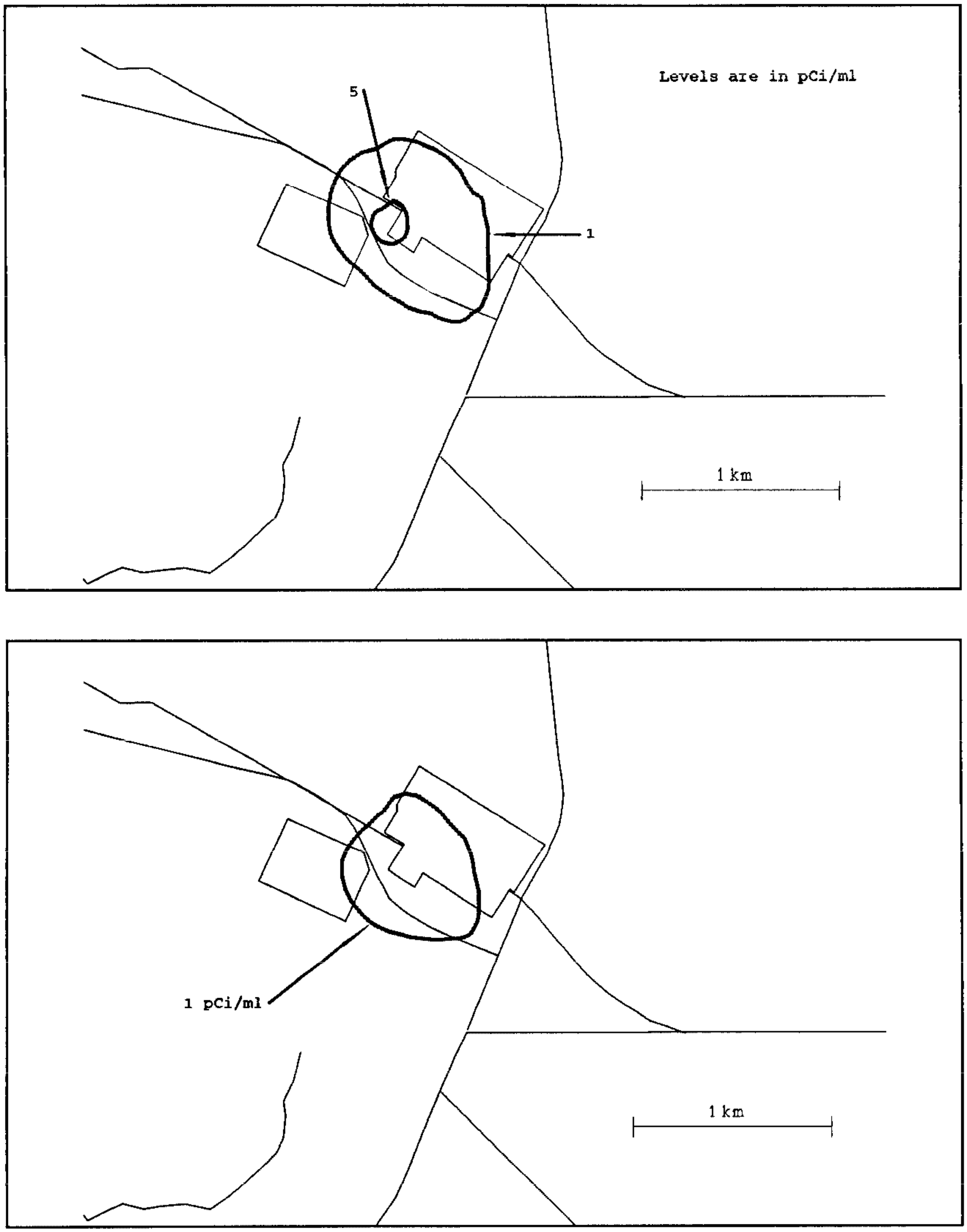


Figure H-8d. Concentration contours of ^3H for the years 1995 and 2005, simulated using steady-state heads of January 1990.

Extremely large values of the longitudinal and transverse dispersion were necessary to obtain the modeled plume thickness. The dispersion coefficient is a term used to account for mechanical mixing of solutes as the water flows around and between sand grains. Typically, the mixing term or dispersion term is much greater in the direction of flow (longitudinal) than transverse to the direction of flow. In these steady-state simulations, the transverse dispersivity was 40, while the longitudinal value was 91. Although not technically correct, using a larger value of transverse dispersivity could have allowed the plume to become wider. A more technically correct method of increasing plume width to a representative or more representative state simply involves including the transient heads.

The transient nature of heads resulting from long-term periodicity in recharge (Figure H-4) can cause a fairly significant variation in groundwater direction. This variation in flow direction allows the contaminant-bearing water to contact a much larger portion of the aquifer than is presumably predicted from the steady-state head approach. As the water contacts more of the aquifer, the contaminants are allowed to degrade radioactively, adsorb onto the rock chemically, and be degraded through contact with micro-organisms. Hence, the plume concentrations predicted by the steady-state approach are most probably overly conservative.

H-7. CURRENT MODELING STUDY

In view of the collected data and information presented by previous modeling efforts, the proposed modeling approach is two dimensional in plan view and assumes vertical averaging.

This modeling study will incorporate the hydrologic features dominating the flow and transport at TAN. These features include:

1. **Varying water levels** caused by recharge from Birch Creek, Little Lost Rivers, and local recharge events. These transient recharge events play a large role in determining the position of the water table (free-surface), thickness of the saturated zone of the aquifer, and ultimately the overall groundwater flow direction.

2. **Variable horizontal hydraulic properties** will be incorporated by allowing the basalt to have transmissivity (hydraulic conductivity), porosity, and storativity values that are representative of values measured at the TAN site.

3. **Variable pumping rates at water supply wells** will be modeled. The pumping wells tend to increase local gradients and locally reverse the regional gradients (drawing water from the south to the north), pulling the contaminants along the flow path or obliquely to the regional flow path. As the pumping rate increases, the degree of pull increases. Decreased pumping rates allow the flow to resume its southeasterly direction. Changing pumping rates result in a side-to-side movement of water, allowing further adsorption, decay, and a much larger net dispersion.

4. **Values of dispersion** will be small and reasonable. This can be accomplished by incorporating the fluctuating water levels. If fluctuating water levels, which aid in mechanical mixing, are ignored, unrealistically high values of dispersion would be needed to simulate the mixing process.

On a very small scale, the aquifer at TAN is an extremely complex three-dimensional system consisting of fractures, basalt matrix, lava vents, and sedimentary interbeds. However, the head and concentration data that have been collected at TAN indicate that, on a large scale, the aquifer behaves as a two-dimensional system. The blocks of basalt act like large sandgrains, and the regional hydraulic gradient is fairly uniform. Although some measurements suggest vertical flow as a factor, the field data and geologic description of the aquifer suggest that the primary flow is horizontal. On the basis of concentration data, which support a vertical mixing model, a two-dimensional areal model should be sufficient to simulate the system. In addition, enough data have been collected to initially parameterize a two-dimensional numerical flow and transport model. Enough data do not exist to parameterize either an unsaturated or three-dimensional saturated numerical flow and transport model, nor is it considered necessary to do so in order to provide a realistic model of the system. Adopting a two-dimensional model does not preclude performing sensitivity studies in the vertical plane. In fact, studies of vertical flow components resulting from the fluctuating water table will be performed to validate the use of a vertically integrated flow and transport model.

In addition to flow and transport in two-dimensions, the primary source of contaminants at TAN supports the use of a saturated flow model. Contaminants at TAN are suspected of entering the aquifer primarily through the two screened intervals of the TAN-INJ well. These screened intervals are between the depths of 180 and 330 ft, which is mostly below the bottom of the unsaturated zone. Because the bulk of contaminants were injected directly into the saturated zone of the aquifer, it is only necessary to model that portion of the aquifer. This approach may neglect some contaminant carried up into the unsaturated region by the fluctuating water table, but the thickness of that region is negligible relative to the total thickness of the aquifer itself.

Another cause of vertical flow might be density effects. If, for example, concentrations of dissolved organic solvents were great enough to result in buoyancy effects, density-driven flow could occur. The weights and concentrations of the organics found at TAN are insufficient to influence the movement of contaminants in the flow system. This is determined by comparing the ratio of dissolved solvent density/water density to one:

$$\beta = \frac{\rho}{\rho_0} - 1 = \frac{0.4 \times 10^6 \text{g/cc}}{1\text{g/cc}} - 1 \approx -1.0$$

The vertical flow equation then becomes

$$Q_z = -K_z \left[\frac{\partial P}{\rho g \partial z} + \beta \right] = -K_z \left[\frac{\partial P}{\rho g \partial z} - 1 \right]$$

which indicates that there is a single fluid only.

In addition, the volume of TCE dissolved in 1 cc of H_2O is given by the ratio of an areally representative near-source (i.e., within one-half mile of the injection well) TCE concentration (400 μg/L = 0.4×10^{-6}g/cc) to the density (1.46 g/cc) of TCE:

$$V_{TCE} = \frac{C_{TCE}}{\rho_{TCE}} = \frac{0.4 \times 10^{-6}\text{g/cc}}{1.46\text{g/cc}} = 2.74 \times 10^{-7}\text{cc of TCE}$$

This extremely small number indicates a very dilute solution, a single fluid phase, and negligible density effects.

These calculations suggest that density differences between the dissolved injected fluids and the ambient groundwater should be neglected. At this point, there is no field data to support the existence of non-dissolved contaminants at TAN. Based upon the current data, it is considered sufficient to model only dissolved contaminants.

The proposed modeling approach can be used to produce results that are conservative from a risk-assessment point of view. For example, if in actuality there are vertical flow components, the total horizontal movement will be less than predicted by a vertically integrated flow approach. In addition, concentrations predicted by a vertically integrated flow approach will be slightly higher than predicted by a three-dimensional model with similar total thicknesses. The degree of conservatism can be adjusted in the final modeling process by varying the input parameters within physically realistic ranges as a part of the sensitivity study.

H-8. MODEL SELECTION CRITERIA

A vertically integrated two-dimensional (in plan view) model with the capability of simulating the free surface of the water table, time varying boundary, first and/or second type boundary conditions, and multiple time-varying sources and sinks is required to simulate the groundwater at TAN for the RI/FS.

Criteria for selecting a model for the TAN RI/FS are:

1. Capability of producing a conservative estimate of flow and transport from a risk-assessment perspective if realistic and defensible.

2. Capability of simulating two-dimensional transient vertically integrated flow, i.e. the Boussinesq equation:

   $$N + S \frac{dh}{dt} = \nabla K h \nabla h$$

   where

   N = local recharge

   S = storage coefficient

   t = time (day)

   K = hydraulic conductivity (ft/day)

   h = hydraulic head (ft)

   ∇ = gradient operator (1/ft),

   which is valid as long as the flow is primarily horizontal. The flow at TAN is primarily horizontal with minor vertical flow near the water table due to pumping.

3. Capability of simulating a highly periodic free-surface water table without resorting to solving the Richard's equation for unsaturated flow, accomplished by solving the Boussinesq equation and preferably by allowing a dynamic time-stepping solution.

4. Capability of simulating transient first- or second-type boundary conditions at a time interval of days without resorting to infinitesimal time steps, where the first- and second-type boundary conditions are input in functional as opposed to table form. This is necessary to reduce the storage requirements of the code, reduce the amount of data manipulation, and simplify the coupling of the flow code to the transport code.

5. Capability of including heterogeneous horizontal hydraulic conductivity and storage coefficient within the simulated domain.

6. Capability of either an internal or complimentary external solution of the advective-dispersion transport equation based upon transient velocities (v) mathematically consistent with the formulation of the flow model

$$v = \frac{Kh}{\phi}\nabla h$$

$$R_d\phi\frac{\partial C}{\partial t} + v\frac{\partial C}{\partial x_i} = \frac{\partial}{\partial x_i}\left(D_m\phi\frac{\partial C}{\partial x_i}\right) - \lambda R_d\phi C + \dot{m}$$

where

phi = effective porosity

v = groundwater flow velocity (ft/day)

C = species concentration (g/cc)

R_d = retardation factor

D_m = mass dispersion coefficient

λ = decay constant

$\dot{m}$ = mass source term (g/day)

x_i = coordinate direction (ft).

We point out that there are uncoupled transport codes that, with additional data manipulation, will accept output in the form of velocities from flow codes. These manipulations are often not mass conservative, and are completely intractable from an implementation point of view in highly dynamic systems. In addition, non-coupled flow and transport codes force the use of the same spatial and temporal discretization for both solutions. We see the use of a very large system to incorporate the influences of Birch Creek and the Little Lost and Big Lost rivers at TAN. A separate (finer) discretization will be used for simulating the transport, which occurs at a much more localized scale near the TSF. In order to perform the re-discretization between flow and transport, the coupling of the codes must be mass conservative and easily implemented.

7. Capability of simulating advection (v), dispersion (D^m), adsorption (R^d), and radioactive decay (λ) of contaminants.

8. Code compatibility with existing computational environments at the INEL, which include the UNIX-SUN and UNICOS-CRAY platforms.

9. Adequate code documentation and graphical presentation capabilities.

10. Availability of the source code, documentation, and bench-mark tests for independent review.

The models considered for the TAN RI/FS simulation are given in Table H-7.

Preference is given to public domain codes, as per the guidelines set forth in the *Report of Findings and Discussion of Selected Groundwater Modeling Issues* (van der Heijde, 1986). Some of these codes can be disqualified based on lack of either transport capability or the ability to handle the dynamic water-table conditions. The capabilities of these codes relative to this modeling study are given in the following section.

Table H-7. Flow models to be considered for use in TAN RI/FS simulations.

BIOPLUMEII	FLASH	NWFT	SUTRA	USGS2D
COOLEY	HST3D	PORFLO-3D	SWIFTII	USGS3D
DSTRAM	MAGNUM-2D	SEGOL	TARGET-2DH	V3
FE3DGW	MAGNUM-3D	SATURN	TRACER3D	VAM2D
FEMWATER	MODFLOW	SEFTRAN	TRAFRAP-2DT	VS2D
FLAMINCO	MOFAT	SHALT	TRUST	VTT

H-9. MODEL SELECTION SCREENING

Groundwater flow and contaminant transport models that are presented in Table H-7 are described in Table H-8. The information in these tables was obtained from van der Heijde et al. (1988), Bond and Hwang (1988), and Dames & Moore (1985). The models in these tables were selected based on previous code reviews, and were thought initially to be capable of simulating either the flow or transport processes occurring at TAN: unconfined, transient, saturated, and horizontal flow, with advective, adsorptive, dispersive, and radioactive contaminant transport. All of the numerical models listed (finite difference and finite element) can simulate two-dimensional flow with the exception of NWFT/DVM, which is a one dimensional finite difference code capable of simulating flow and transport in one-dimensional water-table aquifers.

Table H-8 lists relevant information about each model, arranged alphabetically according to the name of the model. Table H-9 indicates whether each model satisfies the eight criteria listed previously in Section 8.

On the basis of the code selection criteria, seven of the codes (COOLEY, FE3DGW, SEFTRAN, USGS2D, USGS3D, V3, VAM2D, and VTT) were disqualified because they lacked a transport component.

Two codes (SATURN2, and VS2DT) were disqualified on the basis of handling only vertical flow as opposed to horizontal flow required to model groundwater flow movement at TAN. One code (NWFT/DVM) was disqualified on the basis of handling only one-dimensional flow, and one (HST3D) on the basis of performing only steady-state flow.

Of the remaining twenty codes, only TARGET-2DH and MODFLOW actually solve the Boussinesq equation. Instead of eliminating all of the others, codes solving the variably saturated equations were considered further. Solution to the variably saturated flow problem involves dealing with non-linear hydraulic conductivity - head K(h) relationships. The equations can easily be massaged into the Boussinesq equation by letting the functional relationship between

Table H-8. Relevant groundwater model capabilities/numerical model descriptions.

Code	Author	Computer	Documentation	Public Domain	Dimensionality	Orientation	Spatial Discretization	Temporal Discretization	Boussinesque Equation	Heterogeneity	Transient h,g	Variably Saturated	Transport Code	Advection	Dispersion	Retardation	Radio-Decay
BIOPLUME II	Rice U	???	●		2	H	D	FDT		●	I	N	●	●	●	●	●
COOLEY	DRI	???	●	●	2	H,V	E	FDT		●	I	YP					
DSTRAM	HGLI	???			2,3	H,V	E	FDT		●	I	N	●	●	●	●	●
FE3DGW	PNL	CRAY	●	●	3	–	E	FDT		●	I	N					
FEMWATER	AEC	IBM360			2	H	E	FDT			I	YFP	●	●	●	●	●
FLAMINCO	GEOT	???	●		3	–	E	FDT		●	I	YF	●	●	●	●	●
FLASH	EG&G	C/S	●	●	2	H,V	E	DDT		●	I	YPN	●	●	●	●	●
HST3D	USGS	CDC	●	●	3	–	D	FDT		●	N	N	●	●	●	●	●
MAGNUM2D	EG&G	C/S	●	●	2	H,V	E	FDT		●	I	N	●	●	●	●	●
MAGNUM3D	EG&G	C/S	●	●	2,3	–	E	FDT		●	I	N	●	●	●	●	●
MODFLOW	USGS	CDC	●	●	3	–	D	FDT		●	I	N	●				
MOFAT	EST	EST			2	H,V	E	FDT		●	I	Y	●	●	●	●	●
NWFT/DVM	SNL	???		●	1	H	E	FDT	●		I	N	●	●	●	●	●
PORFLO-3D	ACRI	???	●		3	–	D	FDT		●	I	Y	●	●	●	●	●
SEGOL	BECHTEL	???	●	●	3	–	E	FDT		●	I	Y	●	●	●	●	●
SATURN2	GEOT	???			2	V	E	FDT		●	I	Y	●	●	●	●	●
SEFTRAN	GEOT	???			2	H	E	FDT		●	I	N					
SHALT	INTERA	PC	●		2	H	E	FDT		●	I	YF	●	●	●	●	●
SUTRA	USGS	CDC	●	●	2	H,V	E	FDT		●	I	YF	●	●	●	●	●
SWIFTII	SNL	CRAY	●		3	–	D	FDT		●	N		●	●	●	●	●
TARGET-2DH	D&M	PC/S	●		2	H		FDT	●	●	N	N	●	●	●	●	●
TRACER3D	LANL	CRAY			3	–	D	FDT		●	I	YP	●	●	●	●	●
TRAFRAP-WT	IGWMC	???	●	●	2	H	E	FDT		●	I	N	●	●	●	●	●
TRUST	LBL	???		●	1,2,3	–	D	FDT		●	I	YF	●	●	●	●	●
USGS2D	USGS	CDC	●	●	2	H	D	FDT	●	●	I	N					
USGS3D	USGS	CDC	●	●	3	–	D	FDT		●	I	N					
V3	ISWS	???	●	●	1,2,3	–	D	FDT		●	I						
VAM2D	HGLI	???	●		2	H,V	E	FDT		●	I	YN					
VS2DT	USGS	CDC	●	●	2	V	D	FDT			?	YF	●	●	●	●	●
VTT	PNL	???	●	●	2	H	D	FDT	●	●	N	N					

The following is an explanation of the symbols, and authors appearing in Table H-8:

Symbol	Description
Computer	The type of platform (C/S = Sun and Cray, PC/S = PC and Sun).
Code dimensionality orientation	Whether the codes solves 2- or 3-dimensional flow, with respect to the horizontal (H) or vertical (V) direction.
Spatial discretization	Finite differences [D] or finite elements [E].
Time stepping algorithm	Fixed time step sizes [FDT] or dynamic time step sizes [DDT].
Boussinesq equation	Solved currently by the code yes = • .
Heterogeneity	In hydraulic conductivity.
Transient	Flow and boundary conditions: I=insufficient (non-dynamic, or non-point source); N=steady-state.
Variably saturated	Does the code have a non-linear iterative capability? (N=no, Y=yes, F=fixed point, P=picard, N=newton).
Transport code	Is there an internal or companion transport code?
Advection	Transport includes consistent advective velocities.
Dispersion	Transport includes dispersion.
Retardation	Transport includes retardation.
Radio-Decay	First-order radioactive decay is included.
?	Could not be determined from available documentation.

Source

ACRI	-	Analytic and Computations Research, Inc.
AEC	-	Atomic Energy of Canada
BECHTEL	-	Bechtel Corporation
D&M	-	Dames & Moore
DRI	-	Desert Research Institute
EST	-	Environmental Services and Technology
EG&G	-	EG&G, Inc.
GEOT	-	GeoTrans, Inc.
HGLI	-	HydroGeologic, Inc.
IGWMC	-	International Groundwater Monitoring Center
ISWS	-	Illinois State Water Survey
INTERA	-	INTERA, Inc.
LANL	-	Los Alamos National Laboratory
LBL	-	Lawrence Berkley Laboratory
PNL	-	Pacific Northwest Laboratory
Rice U	-	Rice University
SNL	-	Sandia National Laboratory
USGS	-	U.S. Geological Survey

Table H-9. Code availability and modifiability.

Code Name	Availability (public/private)	Modification Difficulty (us/them)	Changes to Flow/Transport (both)
FEMWATER	Proprietary	Difficult (by them)	Flow
FLAMINCO	Proprietary	Difficult (by them)	Flow
FLASH	Public Domain	Easy (by us)	Flow
MOFAT	Proprietary	Difficult (by them)	Flow
MODFLOW	Public Domain	Difficult (by us)	Both
PORFLO-3D	Proprietary	Difficult (by us)	Flow
SEGOL	Public Domain	Difficult (no documentation, them)	Flow
SATURN 2	Proprietary	Difficult (by them)	Flow
SHALT	Proprietary	Difficult (by them)	Flow
SUTRA	Public Domain	Difficult	Both
TARGET-2DH	Proprietary	Difficult (by them)	Flow
TRACER3D	Public Domain	Difficult (by them)	Flow
TRUST	Public Domain	Difficult (no documentation, us)	Flow

hydraulic conductivity and head take the form: $K(h) = K_{sat}h$, where K_{sat} is the saturated hydraulic conductivity. In the case of finite-element codes, the Boussinesq equation can be implemented rigorously. These remaining codes are listed in Table H-9.

All of the codes appearing in Table H-9 would have to be modified to incorporate the dynamically transient water-table conditions existing at TAN, as well as to actually solve the Boussinesq equation (except TARGET-2DH and MODFLOW which currently solve the Boussinesq equation). As specified in the table, all of the proprietary codes would have to be modified by the code author to our specifications which could take an extensive period of time. Public domain codes having documentation can be modified in-house by EG&G Idaho. Some of the public domain codes are poorly (or not) documented, which increases the time required to understand and make changes to the code.

Of the codes given in Table H-9, four are the best candidates for modification. These codes include FLASH, PORFLO-3D, MODFLOW, and TARGET-2DH, which are evaluated below.

FLASH (EG&G Idaho, 1991) is a two-dimensional, finite element model developed at EG&G Idaho, Inc. The code is well documented (Baca, 1991), and has been benchmarked and validated as a part of other benchmarking/validation studies. The code itself is currently undergoing the complete benchmarking/validation process by an independent group at Washington State. FLASH incorporates a dynamic time stepping algorithm that allows the convergence of mass to dictate the time steps used in solving transient problems. This algorithm allows very efficient solution of highly dynamic fluctuations in water-table elevations without the use of unnecessarily small constant time steps. Output from FLASH consists of the transient heads, velocities, and the spatial discretization used to solve the flow problem at user-selected time planes. This information serves as input to the companion transport code, FLAME, which is also a finite element model developed at EG&G Idaho, Inc. FLAME allows the user to rediscretize portions of the flow domain in order to reduce the overall computational burden while allowing extremely fine resolution of contaminant plumes. The rediscretization is mass conservative, and is based upon consistent spatial interpolation functions using the heads, velocities, and spatial discretization output by FLASH. Both codes have pre- and post-processing capabilities useful in checking input data and outputting the results graphically.

Modifications to FLASH/FLAME involve changes to the code logic in three places to allow the solution of the Boussinesq equation, and to incorporate functional forms for transient head and flux boundary conditions. The modifications for transient heads and fluxes would simply require changing the table-lookup procedure currently used to an evaluative function that is user-constructed. Incorporating the Boussinesq equation simply requires the hydraulic conductivity appearing in the code to be modified by multiplying it by the saturated thickness (hydraulic head). These modifications are extremely easy to incorporate primarily because of the very structured nature of the FLASH code. There are no necessary modifications to the FLAME code.

Adopting the two-dimensional FLASH/FLAME model will allow the performance of sensitivity studies in the vertical plane. The study of vertical flow components resulting from the fluctuating water table will be performed to validate the use of the vertically integrated flow and transport model.

Use of FLASH/FLAME enables us to quickly adopt a three-dimensional approach if necessary. For example, if data collected in the spring/summer of 1992 at TAN indicate the need for a 3-dimensional flow and transport model, and adequate data exist at that point, MAGNUM-3D/CHAINT can be used with minor modifications to the input deck.

The history of use of FLASH/FLAME is limited due primarily to its rather recent development. The modeling staff at EG&G Idaho, however, is very familiar with this code and can modify it quickly.

PORFLO-3D is a three-dimensional finite difference model, developed by Analytic and Computations Research, Inc. (ACRI). Hall et al. (1990) found that "organization of previous code and documentation updates seems to have been rather haphazard," but the code is well verified. It has been used widely. PORFLO-3D is a powerful model with a user-friendly key word oriented preprocessor. Because PORFLO is currently used at EG&G Idaho, several post-processing routines for output are available.

Modifications to PORFLO-3D would include incorporating a dynamic time-stepping algorithm to make computations of flow and transport at the TAN site computationally realistic. In addition, modifications would include adding the dynamically transient boundary conditions and incorporating the Boussinesq equation. With these modifications, PORFLO-3D would be able to solve the head and concentration distributions at TAN. However, the same high resolution computational grid used for transport would also have to be used to solve the head distribution, making PORFLO-3D very inefficient in terms of computational space and computational time.

MODFLOW is a modular two- and three-dimensional finite-difference model developed by the USGS (McDonald and Harbaugh, 1984). The documentation for MODFLOW is complete, the code has been verified, and it has been used widely. MODFLOW is a powerful model with an extensive user interface developed for the personal-computing platform. MODFLOW is currently not used at EG&G Idaho on mainframe platforms and would require the development of appropriate pre-processing routines and application of additional post-processing routines for the workstation environment. We note that these pre- and post-processing routines currently exist for the slower MS-DOS machines, and also note that the development of similar features for the workstation environment would require a relatively small effort.

Modifications to MODFLOW would include incorporating a dynamic time-stepping algorithm to make computations of flow and transport at the TAN site computationally realistic. In addition, modifications would include adding the dynamically transient boundary conditions in functional form.

The code currently solves the non-linear Boussinesq equation using a fixed-point iteration method that is much less efficient than the Newton-type iteration used in FLASH. With the modifications to incorporate the different boundary conditions, MODFLOW would be able to solve the head distributions at TAN. However, although MODFLOW is capable of solving the flow equations, MODFLOW does not currently have a fully coupled transport component. We note that the USGS is currently in the process of finalizing the code documentation, verification, and validation for a three-dimensional method of characteristics (MOC-3D) transport code for use with MODFLOW that should be available in the summer of 1992 (Prince, 1991).

In addition, there has been a three-dimensional transport code (MT3D) written to work with MODFLOW by Zheng (1990) of Papadopulos and Associates. MT3D was developed for the personal computing environment, and is available in source and executable code format with documentation upon purchase. MT3D was written in Fortran 77 and could be adapted for use on a workstation platform. As with MODFLOW, it would be more efficient to develop appropriate pre- and post-processing routines for the workstation environment.

The major disadvantage of using the MT3D code is presented by the inflexibility in gridding. For example, the same high resolution computational grid and temporal time discretization used for transport would also have to be used to solve the head distribution, resulting in a projected order of magnitude increase in the numbers of grid cells and time steps used in the flow model.

Published applications of MT3D are limited, due primarily to its relatively recent development. However, MT3D is purported to be relatively slow for average transport problems by existing code users (Donohue et al., 1992). It is unknown if the computational time requirements were due to excessive problem size performed on the computing platform for which the code was developed or due to the algorithm itself. In addition, from a phone conversation with Ackerman (USGS-Idaho) in February 1992, we found out that MT3D has not been accepted as the primary transport companion for MODFLOW by the USGS.

Considering MODFLOW's lack of time stepping alternatives, and non-dynamic boundary conditions coupled with MT3D's computational requirements, the use of this code pair is not desirable.

TARGET-2DH is a two-dimensional finite-difference model developed by Dames & Moore (1985). TARGET-2DH will solve the Boussinesq equation for simple boundary conditions. It was developed to run on personal-computing machines so porting the code to a SUN or CRAY environment should not pose a problem. However, it has come to our attention that the source code for TARGET-2DH, necessary to incorporate complex boundary conditions, is not available. The source code would have to be modified by Dames & Moore, making it difficult to validate their modifications.

In addition to the boundary condition modifications, it would be necessary to incorporate a dynamic time-stepping algorithm to make computations of flow and transport at the TAN site computationally feasible. This modification would be necessary especially in view of the codes inability to specify a different computational grid for flow and transport. Without the time-stepping modifications, TARGET-2DH would be unable to solve the head and concentration distributions within the TAN modeling schedule. In addition, the EG&G Idaho modeling group is unfamiliar with TARGET-2DH.

H-10. RECOMMENDATIONS

We propose the use and modification of the FLASH/FLAME flow and transport codes for modeling groundwater flow for the TAN RI/FS. The main reasons are:

- Once modified, FLASH/FLAME will satisfy all the criteria deemed necessary
- FLASH/FLAME is easily modified to solve the Boussinesq equation, which is necessary to solve for water-level distributions at TAN
- FLASH/FLAME is easily modified to allow functional forms expressing the dynamic boundary conditions existing at TAN
- FLASH/FLAME currently will handle large variability in time-stepping through the use of a dynamic algorithm
- FLASH/FLAME will handle the horizontally heterogeneous physical properties that exist at TAN
- FLASH/FLAME will effectively handle the advection, dispersion, retardation, and radioactive decay aspect of flow and transport at TAN
- FLASH/FLAME has a comprehensive suite of pre- and post-processing routines designed to aid in the display and interpretation of results
- FLASH/FLAME currently runs within the computing environment at EG&G Idaho
- FLASH/FLAME is familiar to the modeling group at EG&G Idaho and can be quickly modified without affecting the RI/FS schedule.

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Appendix I

Number

APPENDIX I

WATER BALANCE CALCULATIONS FOR THE TSF-07 DISPOSAL POND

APPENDIX I

WATER BALANCE CALCULATIONS FOR THE TSF-07 DISPOSAL POND

A water balance was calculated to evaluate the impact that infiltration from the TAN TSF-07 disposal pond may have on the aquifer potentiometric surface. Input data consists of:

- Water supply well pumping rates, process water discharge, and sewage plant discharge [obtained from the Industrial Waste Management Information System (IWMIS)]
- Aquifer test data from perched water wells completed in the suspected perching layer beneath the TSF-07 pond and from aquifer wells
- Pan evaporation data [obtained from the National Oceanic & Atmospheric Administration (NOAA)].

The calculations conducted as part of this water balance are presented in Attachment 1.

The water balance equation (illustrated in Figure 1) for the TSF-07 pond is

$$WW_{in} = ET + GW_{out} \pm dS \qquad (1)$$

where

WW_{in} = waste water discharge to the pond

ET = evaporation

GW_{out} = flux into the groundwater system

dS = change in storage within the pond.

Assuming that infiltration from the ponds has reached steady state with the associated perched water body, the storage term will go to zero. This is probably a reasonable assumption because the ponds have been in use for about 35 years. The time-weighted average flux into the pond for the year 1990 is about 280,000 ft^3/month. The time-weighted pan evaporation as calculated by NOAA is about 0.30 ft/month. By applying the most common pan to lake correction factor of 0.7,[a] the estimated pond evaporation is 0.21 ft/month. The area of the two disposal ponds within the TSF-07 pond berm is 53,400 ft^2, so the calculated pond evaporation rate is 11,000 ft^3/month. This leaves about 270,000 ft^3/month (46 gal/minute) to infiltrate down to the water table.

Darcy's law can be used to calculate the area of the perched water body, and is given by

$$Q = K I A \tag{2}$$

where

K = hydraulic conductivity

I = gradient

A = cross sectional area through which groundwater flows

Q = discharge.

Assuming that the perched water body has reached steady state with respect to infiltration from the ponds, the approximate size of the perched water body can be calculated by solving for A:

$$A = \frac{Q}{K I} \tag{3}$$

By using the calculated infiltration rate of 270,000 ft^3/month, and by using the hydraulic conductivity value calculated from slug tests conducted on wells completed within the suspected perching layer of 0.04 ft/day, and assuming a unit gradient and a radius of 270 ft, the calculated cross sectional area of the perched water body is 220,000 ft^2.

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a. Winter, T.C., 1980, "Uncertainties in Estimating the Water Balance of Lakes," *Water Resources Bulletin, Vol. 17*, No. 1, pp. 82-115.

The Thiem equation will be used to calculate the effect that infiltration from the perched water body may have on the aquifer. The Thiem equation is

$$s = \frac{Q}{2\pi T} \ln \frac{r_o}{r_w} \tag{4}$$

where

Q = flux into the aquifer

T = aquifer transmissivity

r_o = radius at which no influence from the flux is observed

r_w = radius over which the flux is applied.

This approach assumes that the entire flux to the aquifer behaves as a large-diameter injection well. Using the calculated infiltration rate of 270,000 ft^3/month and the calculated radius of the perched water body of 270 ft, and assuming that there is no measurable impact on the water table at 2,700 ft, and an aquifer transmissivity of 14,000 ft^2/day,[b,c] the calculated rise in the water table beneath the perched water body would be about 0.2 ft. Assuming that r_o is 2,700 ft is a conservative assumption. Assuming a smaller r_o will yield a smaller s in the Thiem equation.

The Thiem calculations will be tested using the Neuman equation. The Neuman equation will be used because the aquifer is unconfined. The Neuman Equation is

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b. The transmissivity of 14,000 ft^2/day is from USGS-24. It was used in lieu of the calculated transmissivity for the TSF-INJ (ANP-3) well because the aquifer test for this well was conducted in 1988, after it had been used for waste disposal for 33 years. During this time, particles of waste could have plugged many of the pores in the aquifer adjacent to the well, locally reducing the aquifer transmissivity. Therefore, the calculated transmissivity from this test may not be representative of the undisturbed aquifer at TAN.

c. Ackerman, D.J., 1991, "Transmissivity of the Snake River Plain Aquifer at the Idaho National Engineering Laboratory, Idaho," *U.S. Geological Survey Water-Resources Investigations Report*, 91-4058, pp. 35.

$$s = \frac{Q\ W(u_b, \frac{r}{D})}{4\ \pi\ T} \tag{5}$$

where

Q = flux into the aquifer

T = aquifer transmissivity

$W(u_b, r/D)$ = well function selected from a table of values.

Using the same values as above and assuming that the system would reach steady state in 30 days, the calculated rise in the water table beneath the perched water body should be about 0.2 ft. The Neuman and Thiem calculations produce similar values using somewhat different assumptions, suggesting that the calculated ground water rise is reasonable.

Assuming that the distance to the point at which no effect can be measured is about 3,000 ft, the gradient associated with the edge of the groundwater mound would be about 1 X 10^{-4}. The regional gradient at TAN is about 2 X 10^{-4}. The addition of the groundwater mound could increase the gradient in the vicinity of the TSF-07 pond by about 50%. Therefore, infiltration from the pond may create mounding, which could impact groundwater flow paths in the vicinity of the pond; however, the impact will be small. In other words, the gradient will go from 1 ft per mile to 1.5 ft per mile, a relatively small increase compared to impacts from the production wells. Figure 2 shows the location of the TSF-07 pond in relation to the TCE plume. Note that the main body of the pond is up gradient from the TCE plume, and that pumping from the TAN water supply well has a much greater impact on the water table than the mound beneath the pond.

In summary, a water balance was calculated to estimate the effects that infiltration from the TAN TSF-07 disposal pond might have on the aquifer potentiometric surface. The data and assumptions used in these calculations include flux into the ponds obtained from IWMIS, hydraulic conductivity data obtained from aquifer tests, pan evaporation data from NOAA, and assuming the pond and associated perched water body are in steady state. The calculated infiltration rate is about 270,000 ft^3/month (46 gal/minute) the calculated area of the perched water body is 220,000 ft^2, and the calculated rise in the water table beneath the perched water body was about 0.2 ft. Therefore, infiltration from the ponds could have a measurable effect on groundwater flow paths. However, pumping from the TAN area water supply wells will have a more pronounced effect on plume migration, but both appear to act together to change the flow path from the southeast to east-southeast.

All equations used in these calculations can be found in any standard groundwater hydrology text. These calculations assumed homogeneous and isotropic media and steady-state conditions. Because of the fractured nature of the aquifer and fluctuations in water use at TAN, the actual impact to the system might be somewhat different than these calculations indicate.

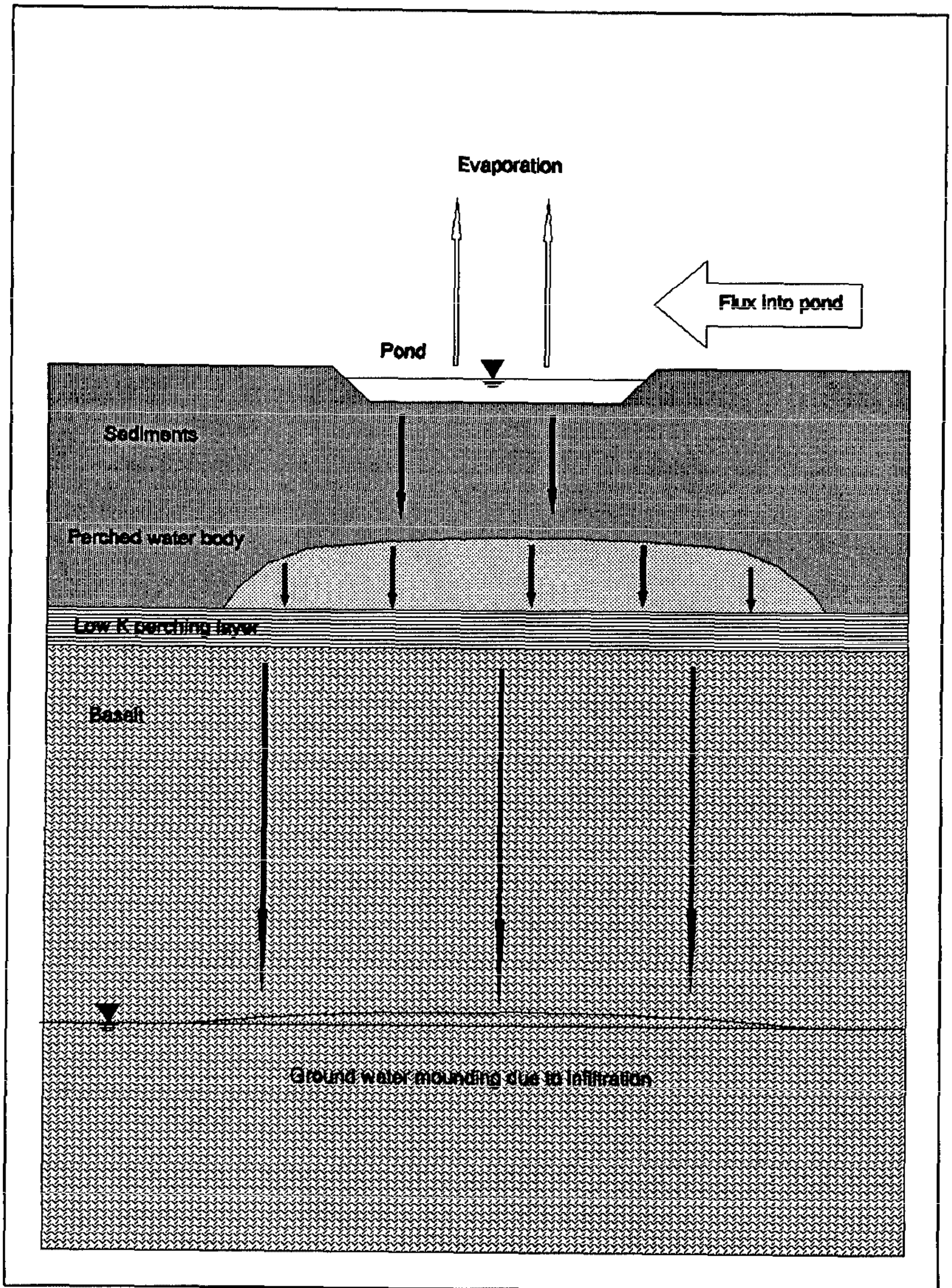

Figure 1. Illustration of the TSF-07 pond water balance.

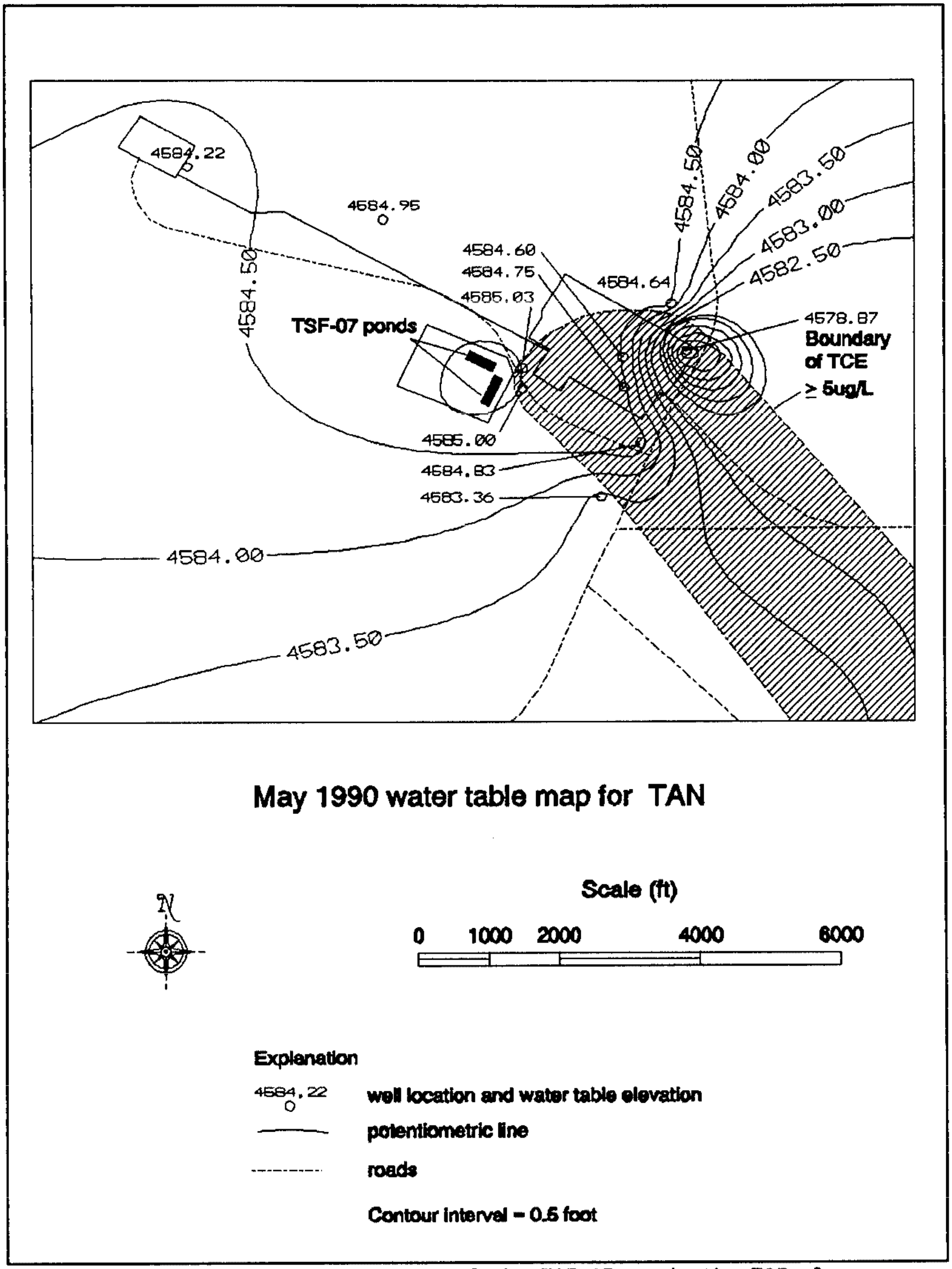

Figure 2. Map showing the location of the TSF-07 pond, the TCE plume, mounding beneath the pond, and a TAN water supply well pumping at 1,060 gpm.

ATTACHMENT 1, CALCULATIONS

Variable assignments

$area1 := 650 \cdot ft \cdot 60 \cdot ft$ — area of pond 1

$area2 := 320 \cdot ft \cdot 45 \cdot ft$ — area of pond 2

$pet := 0.2986 \cdot \frac{ft}{mo}$ — pan evaporation, from NOAA

$Qin := 25389000 \cdot \frac{gal}{yr}$ — Total flux into ponds for 1990, from IWMIS

$K := 0.04 \cdot \frac{ft}{day}$ — hydraulic conductivity of sediments beneath TSF07 ponds, from aquifer test data

$I := 1$ — vertical hydraulic gradient

evaporation calculations

$area := area1 + area2$ $\quad area = 5.34 \cdot 10^4 \cdot ft^2$ — Total ponded area within TSF07 pond

$Qin = 2.83 \cdot 10^5 \cdot \frac{ft^3}{mo}$ — monthly influx into ponds

$et := pet \cdot .7$

$et = 0.21 \cdot \frac{ft}{mo}$

evaporation rate from ponds obtained by applying the most common pan to lake correction factor of 0.7

$ET := et \cdot area$

$ET = 1.12 \cdot 10^4 \cdot \frac{ft^3}{mo}$

total evaporation per month is obtained by multiplying the evaporation rate times the area

calculation to determine flux into the ground water system

$Qgw := Qin - ET$

$Qgw = 8.93 \cdot 10^3 \cdot \frac{ft^3}{day}$

flux into the ground water equals the total flux minus the volume lost to evaporation calculations to determine the approximate size of the perched water body

$$pw\_area := \frac{Qgw}{K \cdot I} \qquad pw\_area = 2.23 \cdot 10^{5} \cdot ft^{2}$$

$$rw := \sqrt{\frac{pw\_area}{p}}$$

$$rw = 2.67 \cdot 10^{2} \cdot ft$$ radius of perched water body

ground water rise calculations using the Thiem equation

$$T := 14000 \cdot \frac{ft^{2}}{day}$$ aquifer transmisivity

$$ro := 2670 \cdot ft$$ radius at which no drawdown is observed (estimated value)

$$rw = 2.67 \cdot 10^{2} \cdot ft$$ radius over which the flux is applied

$$\left[\frac{Qgw}{2 \cdot p \cdot T} \cdot \ln\left[\frac{ro}{rw}\right]\right] = 0.23 \cdot ft$$ ground water rise beneath the TSF07 pond using the Thiem equation

ground water rise calculations using the Neuman equations

$$\frac{rw^{2}}{(200 \cdot ft)^{2}} = 1.78$$ calculate r/D

$$t := 30 \cdot day$$ assume steady state will be reached in 30 days

$$ub := \frac{\left[rw^{2} \cdot 0.01\right]}{(4 \cdot T \cdot t)}$$

1/ub calculations

$$\frac{1}{ub} = 2.37 \cdot 10^{3}$$

$$Wub := 4.91$$ "well function" (W(ub,r/D)) picked from a table of values using the r/D and ub values

$$\frac{(Qgw \cdot Wub)}{[4 \cdot p \cdot T]} = 0.25 \cdot ft$$ ground water rise beneath the TSF07 pond using the Neuman equation

Appendix J

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APPENDIX J

TAN PUMPING TEST RESULTS (1953-1987)

by

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January 1989

INTRODUCTION

Nine wells in the Test Area North (TAN) have had one or more pumping tests conducted in them between 1953 and 1987. Table 1 lists the wells, dates, duration, pumping rate, specific capacity and other pertinent data from these tests. Figure 1 shows the locations of wells in the TAN area. Five pumping tests were conducted in 1987. These tests were conducted by the USGS and the data was provided to EG&G, Idaho, Inc. for interpretation as part of the RFI of TAN.

A number of pumping tests were conducted in the TAN area in the 1950's. These tests were conducted by the USGS and utilized higher discharge rates over longer periods of time than the 1987 tests. The 1950's pumping tests were documented and published in several reports by the USGS. These reports summarize the calculated transmissivity and storativity values which were based on standard analytical solutions at the time. The raw field data and most of the plotted and interpreted time-drawdown plots are not given and, therefore, determining the accuracy of the calculated transmissivity and storativity values is difficult.

This report provides an interpretation of the 1987 TAN pumping tests and summarizes the 1950's pumping tests. The 1950's tests of the TAN wells are discussed in a number of USGS documents Walton (1958), Nace, et al. (1959), Walker (1960) and Mundorff et al. (1964).

THE SNAKE RIVER PLAIN AQUIFER NEAR TAN

The TAN facility is situated near the western margin of the Snake River Plain Aquifer. The Snake River Plain Aquifer is defined as a series of basalt flows and interlayered pyroclastic and sedimentary materials which underlie the Snake River Plain east of Bliss, Idaho (Mundorff, et. al., 1964). The Snake River Plain Aquifer extends from Bliss and the Hagerman Valley on the west to Ashton and the Big Bend Ridge on the northeast. Its lateral boundaries are formed at the contacts of the aquifer with less permeable rocks near the margins of the plain. Although

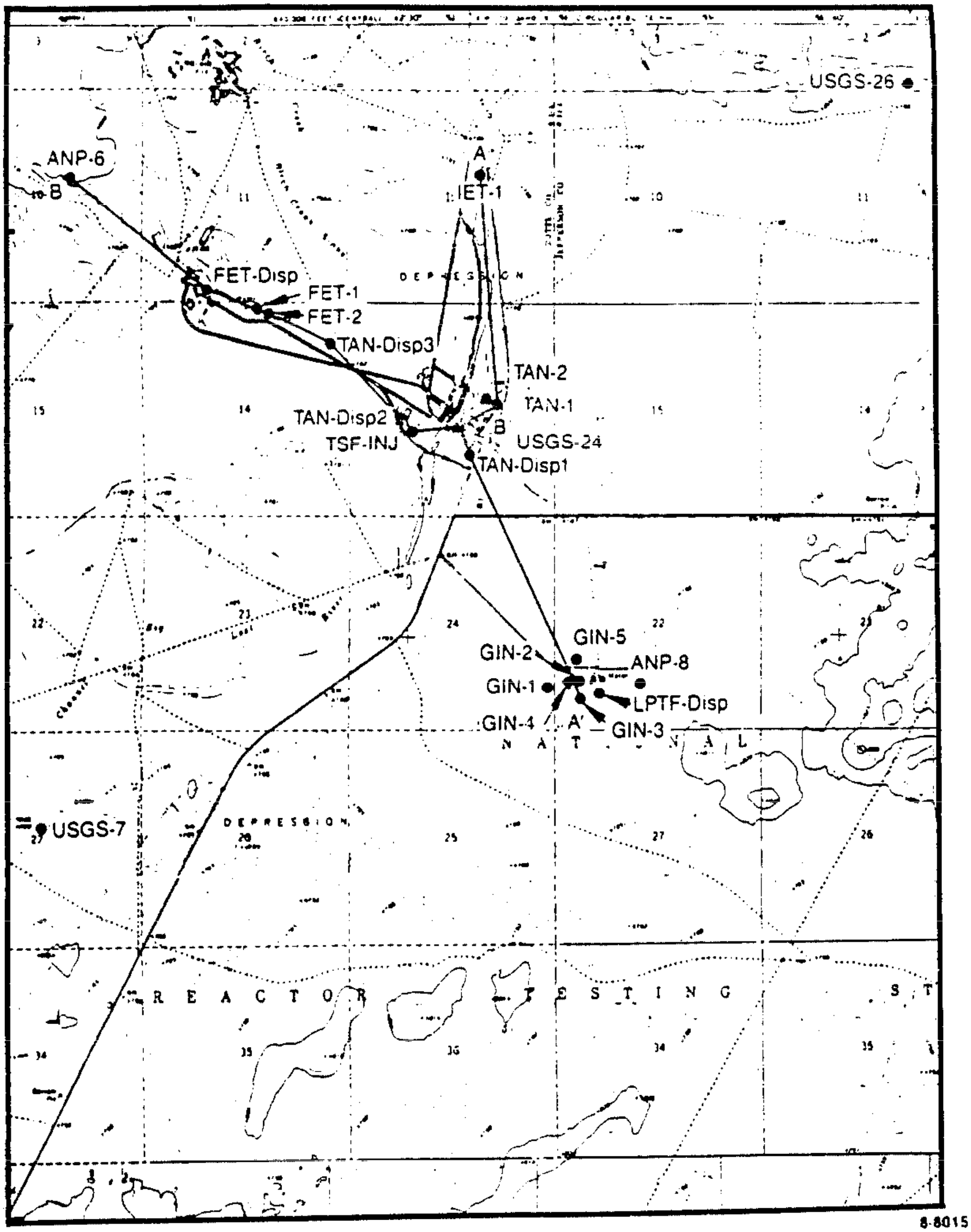


Figure 1. Map showing locations of Test Area North (TAN) wells

Table 1. Summary of pumping tests conducted at TAN, 1953-1987.

Well Number INEL	Well Number USGS	Date of Test	Duration of tests (hours)	Pumping rate (gpm)	Drawdown near end of test (feet)	Specific capacity (gpm/ft)	Penetration below water (feet)	Depth of well (feet)	Static Water Level (feet)	Casing and Perforations (ft. BLS)
TAN-1 (ANP-1)	6N-31E-14ab1	4/17-18/58	16	1,735	12.3	140	139.2	340	201	18", 2-340; perf. 230-330
TAN-2 (ANP-2)	6N-31E-13ac2	11/12-23/53 11/18/87	72 4	1,220 1,010	21.3 7.7	57 131	134	345	211	16", 5-345 Perf. 235-355
TSF-INJ (ANP-3) (TAN disp.)	6N-31E-13ab1	7/13/87	1.3	20	12.7	1.6	81	310	199	12", 2-310; Perf. 180-244 269-305
ANP-6	6N-31E-10ac1	9/5-6/56 7/10/87	23 3	450 40	0.16 none	2,810 ---	91 91	305 305	214 214	10", 2-305; perf. 211-255 266-296
FET-1 (LOFT-1)	6N-31E-14ab1	4/17-18/58	16	1,735	12.3	140	139.2	340	201	18", 2-340; Perf. 230-330
FET-2 (LOFT-2)	6N-31E-14ab2	5/03/58	16	1,820	17.9	100	258.9	461	202	18", 2-453; Perf. 209-448
FET Disp.	6N-31E-11cd1	11/23-24/57	7	643	4.3	149	101	300	199	10", 2-300; Perf. 175-295
IET-DISP	6N-31E-12acd1	7/09/87	2	20	2.4	8.3	100	324	209	12", 11-324; Perf. 219-312
LPTF disp.	6N-32E-22cc1	6/20-21/57	22	615	53.0	12	109	315	206	10", 2-314; Perf. 187-314

a single lava flow may not be a good aquifer, a series of flows may include several excellent water bearing zones. If the sequence of lava flows beneath the Snake River Plain east of Bliss is considered to consitute a single aquifer, it is one of the world's most productive (Mundorff, et al., 1964). The water wells in the TAN area penetrate the upper 100-200 feet of the Snake River Plain Aquifer. As anticipated, based upon the regional setting of TAN in the Snake River Plain Aquifer, most of the TAN wells have high transmissivity, although locally some of the wells have relatively lower transmissivity.

ANALYTICAL METHODS

The 1987 pumping test data were analyzed by two methods, Neuman (1975) type curve matching for an unconfined aquifer and the Cooper-Jacob straight-line method which assumes the aquifer is confined. Detailed discussions of both of these methods are given by Fetter (1980). The Neuman type curves takes into account gravity drainage in an unconfined aquifer and may be more appropriate in the unconfined Snake River Plain Aquifer than the Cooper-Jacob (1946) method. The Cooper-Jacob method is based on a confined analytical model (Theis, 1935) and was used to provide a double-check of the Neuman method. Although, in a majority of the cases, the drawdown-recovery curves did not show gravity drainage and a good correlation was found between the two methods. The analytical methods that took into account gravity drainage were not available at the time of the interpretation of the 1950's tests, therefore, the tests were interpreted using the Theis (1935) solution and the Copper-Jacob (1946) methods. Not addressing the effects of gravity drainage may have caused an over estimation of the transmissivity and storativity values for the 1950's tests.

A well pumping in a water table aquifer extracts water by two mechanisms. Initially, the decline in pressure in the aquifer yields water due to elastic storage (storativity). The declining water table also yields water as it drains under gravity from the aquifer (specific yield) (Fetter, 1980). For the initial pumping phase, the water level decline follows the Theis curve. As time progresses, the rate of drawdown decreases as water drains under gravity from the aquifer. At longer periods of time, when the effects of gravity drainage become smaller, the data again follow the Theis curve.

None of the pumping tests conducted at TAN (or probably anywhere else in the Snake River Plain Aquifer) were conducted long enough to observe the drawdown data following along the Theis curve during the final phase of the tests. The final phase of a pumping test in an unconfined aquifer is critical for defining that, indeed, the aquifer is unconfined and its behavior is controlled by gravity drainage. There are a number of factors which can cause an aquifer to respond as if it were receiving water from gravity drainage. It is estimated that the duration of a pumping test at TAN would need to be at least 20-30 days at 1000 gpm in order to observe the complete Neuman type curve response (Mann, 1989, personal comm.). A pumping test of this magnitude at TAN would be impractical, expensive and would create interpretation problems of its own.

In many cases the plotted data in Appendix A of this report and the earlier USGS reports initially follow along the Theis curve and as time progresses begin to fall to the right of the Theis curve. This is the response which the Neuman analytical method predicts. Falling to the right of the Theis curve indicates less drawdown than predicted for a confined aquifer. There are a number of other factors besides gravity drainage which could cause the data to fall to the right of the Theis curve. These factors include but are not limited to the following:

1. Recharge
2. Constant head boundary
3. The effects of partial penetration and variations in horizontal and vertical K
4. Gravity drainage
5. Changes in barometric pressure
6. Returns from pumpage
7. Leakage across confining layers
8. Nearby wells stop pumping

Factors one and two can be eliminated in the TAN area because prior to and during the pumping tests the annual precipitation rates were low and recharge from constant head boundaries such as rivers and playa lakes was not a possibility. Partial penetration, gravity drainage and leakage across confining layers have similar effects on the drawdown versus time plots. Because several geometric factors are unknown for the aquifer at TAN the effects of partial penetration cannot be corrected (see Appendix A). Gravity drainage and leaky confining layers have very similar type curve solutions for the early and middle time data. Substituting one curve for the other would not introduce as much error as matching, in either case, to the Theis solution. For the TAN wells the leaky confining layers would have to be below the depth of the wells since most of the wells are open from the water table to total depth (the contributions from a lower source should be minimal).

Barometric corrections can cause the data to fall either to the right or the left of the Theis curve depending on the change in atmospheric pressure. Barometric corrections were made to the 1950's data. Barometric corrections could not be made to the 1987 data because the barometric pressures were not recorded. However, due to the very short durations of the tests (less than 4 hours) barometric fluctuations on the 1987 test should be small. Returns from pumpage should not affect the 1987 and the 1950's test data because it would probably take more than 3 days for water to percolate through the overlying sediments to the aquifer. Nearby wells shutting on and off during the tests may have been a factor in the tests, however, because of the high transmissivities and the long distances between wells (hundreds of feet) the effects from this factor would be very small. The above section was summarized from a discussion with USGS personnel (Akerman and Mann, 1989).

It appears that gravity drainage of the dewatered unconfined Snake River Plain Aquifer is the major contributing factor causing the time drawdown plots to fall to the right of the Theis curve. The use of the Neuman analytical solution for an unconfined aquifer is, therefore, the most appropriate technique for analyzing the TAN data which falls to the right of the Theis curve.

The analytical methods used for analyzing the pumping tests assume that the test well is fully penetrating. This is not true for any of the tested wells, in fact, there is some question as to the thickness of the Snake River Plain Aquifer at the INEL. The effects of partial penetration on drawdown in an unconfined aquifer are discussed in Appendix A. It should be noted that the calculated aquifer parameters are approximate values because of the effects of partial penetration.

1987 PUMPING TESTS

The calculations for the 1987 pumping tests are presented in Appendix A. The calculated aquifer parameters are tabulated in Table 2. Drawdown data for the 1987 aquifer tests are given in Appendix B. Figures A1A-A8A are the log-log plots of the data showing the best fit for the Neuman type curves and Figures A1B-A8B are the semi-log plots for the Cooper-Jacob straight-line method. Table 2 shows the results for both the Neuman and Cooper-Jacob methods and an average transmissivity and storativity for the 1987 tests. The averages are based upon the data from Figures A1A-A8A and A1B-A8B.

Several factors effect the quality and reliability of pumping tests. These factors can alter the shape of the time drawdown plots and because the plots are matched to type curves it is important to recognize where the correlation to the type curves could adversely affect the calculated aquifer parameters. Generally, there are several types of errors which can be introduced into the data during testing. Criteria were developed to eliminate data which might introduce an error into the type curve matching technique. Table 3 lists the criteria used to eliminate data from the tabulated values in Table 2 (see footnote in Table 2).

Table 2. Aquifer Parameters Calculated from Pumping Tests in the Test Area North Wells.

Well	Pumped Well	Q gpm	Open Interval (ft B.L.S.)	Water Level (ft B.L.S.)	Saturated Length (b')	D = Drawdown R = Recovery	Neuman Method T x 100,000 gpd/ft	Neuman Method S	Jacob Method T x 100,000 gpd/ft	Jacob Method S	Average Values* T x 100,000 gpd/ft	Average Values* S	K ft/day
TAN-1	TAN-1	1050	200-360	208	152	D	2.8^	-	2.8^	-	2.5	-	220
						R	1.3^	-	3.0^	-			
TAN-2	TAN-1	1050	235-335	211	100	D	0.9^	0.003^	18.0	0.003	1.5	0.004	200
						R	2.0^	0.005^	26.0	0.006			
USGS 24	TAN-1	1050	255-265	215	105	D	11.0^	0.003^	16.0^	0.003^	14.0	0.003	1700
			270-275			R	28.0	0.005	**	**			
			285-375										
TAN-2	TAN-2	1010	235-335	211	100	D	0.9^	-	4.8	-	0.9	-	120
						R	0.9^	-	6.6	-			
USGS 24	TAN-2	1010	255-265	215	105	D	26.0^	0.001^	22.0^	0.002^	21.0	0.002	2700
			270-275			R	5.5	0.02	19.0	0.01^			
			285-375										
TAN-1	TAN-2	1010	200-360	208	152	D	23.0^	0.005^	22.0^	0.004^	23.0	0.005	2000
						R	23.0^	0.005^	22.0^	0.004^			
IET-DISP	IET-DISP	19.99	219-319	209	100	D	***	-	0.5^	-	0.4	-	54
						R	***	-	0.3^	-			
TSF-INJ	TSF-INJ	19.70	180-244	199	81	D	***	-	0.03^	-	0.03	-	5.0
			269-305			R	***	-	0.03^	-			

* Values are based on the average of the reliable pumping test data (see ^ below).
^ Data values used to estimate T and S.
\- Storativity calculations are unreliable from pumped well.
** Inconsistent data.
*** Well bore storage effects.

Table 3. Criteria for eliminating pumping test data from Transmissivity and Storativity Calculations*

1. The number of water level readings must be adequate to record the time-drawdown plots for type curve matching.

2. The range of the recorded drawdown data must be large enough to be distinguishable from changes caused by fluctuations in atmospheric conditions or other background water level changes. These fluctuations can be several tenths of a foot over a 24 hour period in the Snake River Plain Aquifer (Nace, et al., 1959). Barometric pressure was not recorded during the tests, therefore corrections using a barometric efficiency factor cannot be made, but because of the short durations of the 1987 tests, in most cases this correction would be minimal. The short term tests (less than four hours) must have drawdown of at least 0.1 feet to be distinguishable from water level fluctuations caused by changes in weather conditions.

3. Generally, a good correlation between the drawdown and recovery data indicates a reliable set of data were collected. However, changes in barometric pressure, fracture flow phenomenon and other factors can cause the plots of the drawdown and recovery data not to match. Therefore, where mismatches occur and there is not an apparent explanation, the drawdown data was utilized.

4. If the plotted data show evidence of gravity drainage (i.e. the plotted data follow the Neuman type curves), then the Cooper-Jacob method would be inappropriate for calculating T and S.

* The data used for calculating the average T and S values in Table 2 are discussed in the sections on each test.

The following is a well-by-well discussion of the pumping tests conducted at TAN during 1987:

(1) Pumping Test of TAN-1 (11-17-87)

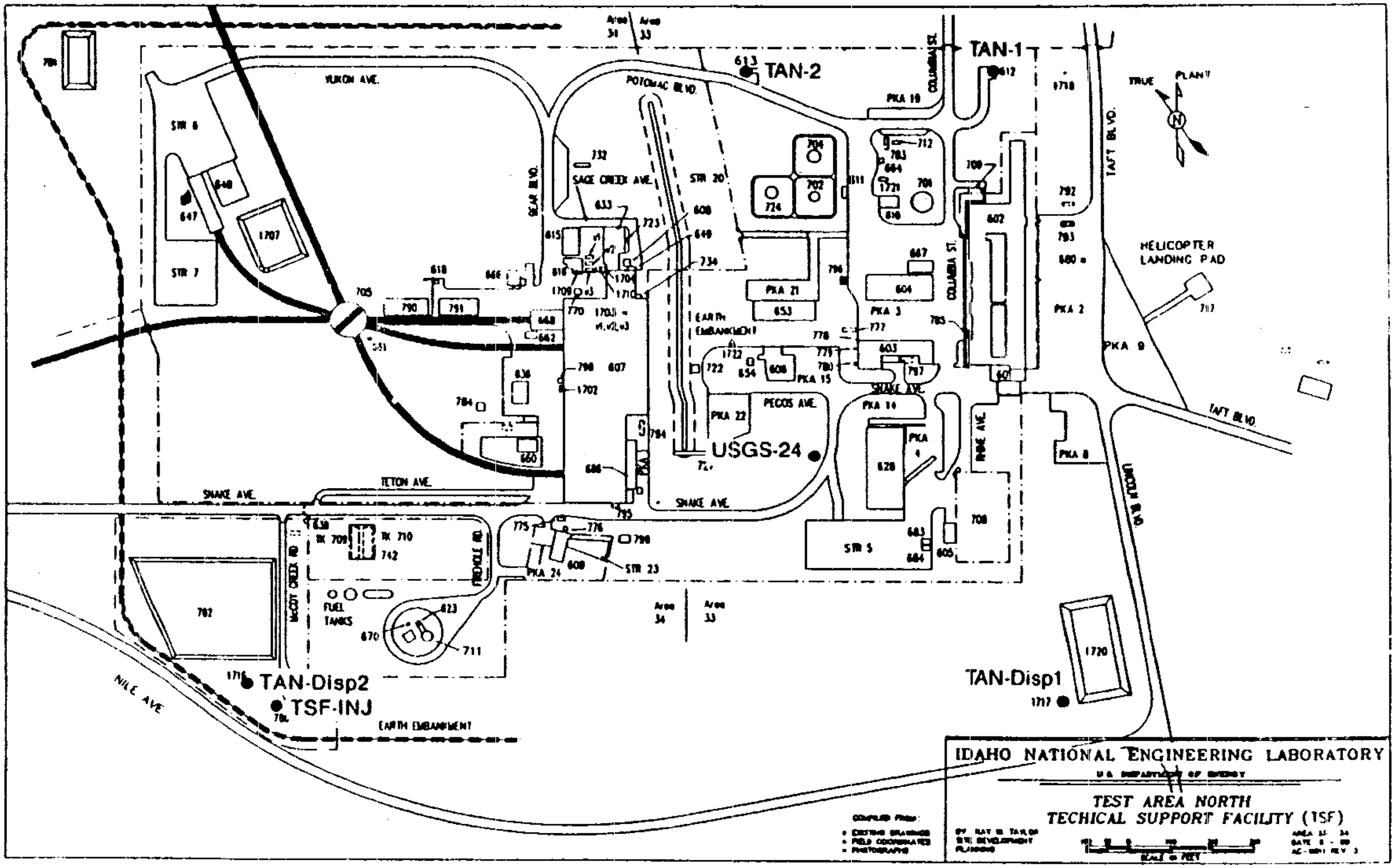
The locations of the wells in the Technical Support Facility (TSF) are given in Figure 2. For the pumping well, TAN-1, the drawdown data follow the Theis curve with the exception of two points in the first minute of pumping (Figure A1A). These two points probably represent extremely high pumping rates at the beginning of the test while the empty pump casing is filled with water. The recovery data show some evidence of gravity drainage. Data plotted on the semi-log graph follow (Figure A1B) a relatively straight line indicating that gravity drainage had a very minor effect on drawdown for this well. The calculations for both methods showed very good agreement (Table 2).

Observation Well TAN-2

This well showed strong evidence for gravity drainage and therefore, only the Neuman method was used for estimating the T and S (Table 2). The early time drawdown for this observation well was not recorded (Appendix B).

Observation Well USGS-24

The drawdown data fit best to the Theis (A) curve (indicating no gravity drainage) and this was confirmed by the Cooper-Jacob method (Figures A3A and A3B). The recovery data showed some evidence for gravity drainage, however, the lack of data points makes the interpretation difficult. In addition, the relatively small drawdown (0.24 feet) may have been effected by changes in barometric pressure (these data were not provided). Only the drawdown data were used for estimating the T and S.



8-8012

Figure 2. Location of the wells in the Technical Support Facility

(2) Pumping Test of TAN-2 (11-18-87)

The pumping well shows a very good correlation between drawdown and recovery and some slight evidence for gravity drainage (Figures A4A and A4B). On the semi-log plot (Figure A4B) there is a second slope that develops after about 50 minutes. Calculations indicate that this is not a well bore storage effect and is probably caused by gravity drainage of the basalts and interbeds of the aquifer. The estimated T in Table 2 is the average of both the drawdown and recovery data.

Observation Well USGS-24

The drawdown data for this observation well follows the Theis (A) curve. Fitting the recovery data to a type curve is difficult because only three data points were collected (Figure A5B). The drawdown data provided a reasonable fit for both the Neuman and Cooper-Jacob methods, and the T and S for this well are estimated based on the average values from both methods using only the drawdown data.

Observation Well TAN-1

The drawdown and the recovery data for this test show good consistency between the drawdown and the recovery phase. There is no evidence for gravity drainage (i.e., the data followed the Theis curve and followed a Cooper-Jacob straight line plot). Both methods were averaged for estimating T and S.

(3) Pumping Test of IET-DISP (7-09-87)

The pumping tests of the IET-DISP and the TSF-INJ well both utilized a discharge rate of approximately 20 gpm. Clearly the transmissivities of these two wells is orders of magnitude less than those of TAN-1 and TAN-2 where a discharge of over 1000 gpm was sustained during the previously discussed pumping tests. The recovery data for the pumping test of IET-DISP shows the best match (Figure A7A) with the type curves. The notes (Appendix B) indicate that the discharge rate decreased at about 10 minutes and was adjusted to compensate. This explains the sudden increase in drawdown at about 15 minutes. The log-log plots follow the Neuman type curves suggesting a delayed response due to gravity drainage. The semilog plot shows two apparent straight line slopes characteristic of well bore storage effects (Driscoll, 1986). Calculations are presented in Appendix A which show that the initial slope is the casing storage effect and the second slope is the response of the aquifer (Figure A7B). The estimated T for this well is based on the second slope using the Cooper-Jacob straight-line method (Table 2) using both the drawdown and recovery data.

(4) Pumping Test of TSF-INJ Well (7-13-87 and 7-11-87)

The largest drawdown for any of the TAN pumping tests was recorded in this well. The semilog plot shows two apparent straight-line slopes characteristic of well bore storage effects (Driscoll, 1986). Calculations are presented in Appendix A which show that the initial slope is the casing storage effect and the second slope is the response of the aquifer (Figure A8B). The estimated T for this well is based on the second slope using the Cooper-Jacob straight-line method (Table 2).

(5) Pumping Test of ANP-6 (7-10-87)

The pumping test conducted in ANP-6 utilized a discharge rate of 40.27 gpm over 180 min. This was insufficient to cause any measurable drawdown. To calculate an approximate transmissivity, conventional solutions could not be used because no drawdown occurred in the borehole. A steady-state approximation method was used, but provides only a minimum value for transmissivity. A minimum transmissivity of 3114 ft^2/day (88.2 m^2/d) was calculated.

A discussion of Logan's method for steady-state flow is given in Appendix C. Based on a saturated thickness of 99.01 feet, the minimum K for well ANP-6 is 31.5 ft/day. These calculated values are minimums only. The actual T and K could be much higher.

1950's PUMPING TESTS

The USGS conducted the pumping tests during the 1950's as part of a regional groundwater study done on the Snake River Plain Aquifer. The results from the pumping tests are given in reports by Walton (1958), Walker (1960), Nace, Stewart, Walton and others (1959), Walton and Stewart (1959) and Mundorff, Crosthwaite and Kilburn (1964). These reports provide summaries of calculated aquifer properties which are given in Table 4.

During the 1950's when the data were interpreted, solutions for the analysis of pumping tests in unconfined aquifers taking into account the effects of delayed yield from gravity drainage had not been derived. Using the Theis curve in an unconfined aquifer tends to over estimate the transmissivity. This is dependent upon the length of the test and the contributions to pumpage from the dewatered portions of the aquifer. It appears that the 1950's pumping test calculations are within an order of magnitude of the 1987 calculations and may be higher by a factor of 3-7 (Table 4).

COMPARISON OF THE 1950's TESTS AND THE 1987 TESTS

Comparing the 1950's pumping tests to the 1987 pumping tests shows several discrepancies, however, a careful examination of these data show the results of the tests are consistent with the complex nature of the Snake River Plain Aquifer. The most obvious difference between the two is that the 1987 data estimated the aquifer storativity on the order of 10^{-3} while the 1987 the 1950's tests put the storativity on the order of 10^{-2}. The difference in storativity is related to the duration of the tests. The 1950's tests averaged about 20 hours while the 1987 tests averaged about 2 hours. Water Table aquifers initially provide water to

Table 4. Transmissivities and storativities for wells in the TAN area, 1953-1987.

Wells						
INEL	USGS	Date of Test	Transmissivity gpd/ft x 10^5	Transmissivity ft^2/day	Storativity	K ft/day
TAN-1 (ANP-1)	6N-31E-13ac1	4/16-17/53 4/30/53 7/20-23/53 11/17/87	7.0 9.5 6.4 2.5 best	33,000	0.01 0.01 0.01 0.005	220
TAN-2 (ANP-2)	6N-31E-13ac2	11/22-23/53 11/18/87	6.4 0.9 best	12,000	0.01 0.004	120
ANP-6	6N-31E-10ac1 6N-31E-10ac1	9/5-6/56 7/10/87	60 best <0.2	800,000	--- ---	2,600
TSF-INJ (ANP-3) (TAN DISP)	6N-31E-13ab1	7/13/87	0.03	400	---	5
IET-DISP	6N-31E-12acd1	7/09/87	0.4	5,400	---	54
FET-1 (LOFT-1)	6N-31E-14ab1	4/17-18/58	3.3	44,000	---	130
FET-2 (LOFT-2)	6N-31E-14ab2	5/03/58	6.8	91,000	---	200
FET-disp.	6N-31E-11cd1	11/23-24/57	5.0 - 10	100,000	---	990
LPTF	6N-32E-22cc1	6/20-21/57	0.3	4,000	---	37
USGS 24	6N-31E-13DB1	ob. well	21 not accurate	280,000	0.003	2,700

pumping from elastic storage (as does a confined aquifer). The declining water table also yields water as it drains under gravity from the fractured basalts and sedimentary interbeds. Therefore, for longer test periods, the storativity value is higher.

Twenty five years ago, Mundorff et al. (1964) noticed the same difference in coefficients of storage calculated from short and long term pumping tests. The authors write:

"When pumping starts, the aquifer acts as an artesian aquifer; the cone around the well expands rapidly. Coefficients determined from data obtained during the early part of the test apply to only the most productive water-yield zone in the aquifer. Within a few minutes, the head on the water-yielding zone in the aquifer declines sufficiently over a large enough area that downward leakage from the overlying basalt supplies a measurable part of the water pumped. At the end of 1 day's pumping, leakage supplies a significant part of the pumpage; after several days' pumping, practically all the water is obtained by downward leakage from the overlying basalt. The aquifer then acts as a water-table aquifer, and the coefficient of storage is the average coefficient of the material dewatered. Because of the continually increasing coefficient of storage during the early part of the pumping, the rate of change in water level will be less than it would have been had the coefficient of storage remained constant. For this reason, the early drawdown data in the computations give coefficients of transmissibility that are too high."

Clearly, the longer tests provide a more accurate measure of the aquifers coefficient of storage.

The second apparent discrepancy in the data occurs between the T calculated from the pumped well and the T calculated in the observation wells. Table 2 shows that TAN-1 has an estimated T of 2.5×10^5 gpm/ft when used as the pumping well. The same well when used as an observation well during the pumping test of TAN-2 had a calculated transmissivity of 2.3×10^6 gpm/ft, an order of magnitude higher. This may be attributed to large amounts of water coming out of storage between the pumping well and the observation well (Akerman, 1989, personal comm.). The observation wells consistently overestimated the transmissivity because of the effects of water coming from storage. This problem is amplified because of the large horizontal offsets (hundreds of feet) between the pumping well and the observation wells.

A comparison of the transmissivity values for the two periods of testing show that the 1950's values range from 3 to 7 times the values calculated from the 1987 tests. As discussed in previous sections of this report, this may be attributed to the interpretation method used for the analysis of the 1950's data. The use of the Theis curve for analyzing pumping test data from a well in an unconfined aquifer showing the effects of gravity drainage will tend to overestimate the transmissivity for that aquifer (Driscoll, 1986). Therefore in Table 4, the values listed as best are from interpretations considering the effects of gravity drainage.

Table 2 shows that the transmissivities of wells tested in the 1987 pumping tests ranged over 4 orders of magnitude. The two lowest values of 4.0×10^4 and 3.0×10^3 gpd/ft were calculated from two injection wells, IET-DISP and TSF-INJ, respectively. It is possible that these two wells were damaged during the injection process by clogging of the perforations and the formation by suspended particles in the injections water or chemical precipitates were deposited in the region of the open portion of the wells. Therefore, these low values may not represent the transmissivity of the aquifer. On the high end of the values in Table 2 are the transmissivities from the observation wells. Because of the effects of high storativity (discussed above) these values are abnormally high. If the highest and lowest values can be eliminated because they do not represent the aquifer transmissivities, the remaining values from TAN-1 and TAN-2 are 2.5×10^5 and 9×10^4, respectively (Table 2). This is in good agreement, considering the different analytical methods with the 1950's USGS calculations of 5×10^5 and 6.4×10^5.

Table 1 shows that for wells TAN-1 and TAN-2 there was an increase in specific capacity from the 1950's to 1987. Apparently the 30 odd years of production pumping has removed fine sediments and drilling mudcake from around the casing and filter pack and increased the specific capacity of the wells. Additionally, during an injection test of TAN-2 (pumping from TAN-1) the observer noticed a sudden decrease in head (back pressure) and this was attributed to the dislodging of a large piece of mud cake from the well bore wall (USGS Field Notes, 1953). This apparently caused an increase in the specific capacity of the well.

Considering the heterogeneities of the Snake River Plain Aquifer, the variations in the duration, pumping rates, and methods of data interpretation, it is remarkable that there is such good agreement between the 1950's tests and those tests conducted in 1987.

CONCLUSIONS

Based on pumping tests conducted in 9 wells at TAN (Table 4) the average transmissivity is 8.5x105 gpd/ft. Without reanalyzing the 1950's tests and understanding that the methods used in the 1950's over estimated the transmissivity in an unconfined aquifer, a reasonable approximation of the transmissivity of the wells at TAN is about 10^5 gpd/ft (13,000 ft^2day). Since none of the wells are fully penetrating, the transmissivity of the Snake River Plain Aquifer at TAN is probably higher. In comparison, an average transmissivity for the Snake River Plain Aquifer, as a whole, is about $5x10^6$ gpd/ft (based upon 33 wells, Mundorff et al., 1964).

The short term tests showed the storativity to be about 10^{-3} while the long terms indicate that the storativity of the aquifer at TAN is about 10^{-2}.

Because of the good correlation among the analyzed data, it appears that further pumping tests in the TAN area wells are not necessary. However, each well is unique in the Snake River Plain Aquifer because of the aquifer heterogeneities and therefore, it is recommended that new wells be tested to determine the well transmissivity.

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APPENDIX A

1987 PUMPING TEST CALCULATIONS OF AQUIFER PARAMETERS: NEUMAN AND COOPER-JACOB METHODS

Partial Penetration

At TAN, production and observation wells do not completely penetrate the Snake River Plain aquifer. The partial penetration of a pumping well influences the distribution of head in its vicinity, affecting the drawdown in nearby observation wells. Walton (1962) and Neuman (1975) provide detailed discussions on the effects of partial penetration. According to Hantush (1961), the effects of partial penetration closely resemble the effects of leakage through a confining bed, the effects of a recharge boundary, the effects of a sloping water table aquifer, and the effects of an aquifer of non-uniform thickness. Butler (1957) and Neuman (1974) give two equations where the approximate distance r_{pp} from the pumped well beyond which the effects of partial penetration are negligible.

$$r_{pp} = 2m\sqrt{Kh/Kv} \qquad \text{(Butler, 1957)}$$

$$r_{pp} = m/\sqrt{Kv/Kh} \qquad \text{(Neuman, 1974)}$$

where:

m = saturated thickness of aquifer, in ft
Kh = horizontal permeability
Kv = vertical permeability

Because of the inhomogeneous and isotropic nature of the basalts at the INEL, the ratio of the horizontal to vertical permeability for the Snake River Plain Aquifer varies from one location to another. As a guide to possible ratios, values obtained from cores and in situ tests (U.S. Atomic Energy Commission, 1969) indicate the ratio might vary from 4 to 70. The saturated thickness of the Snake River Plain Aquifer is not easily determined because of the expense of drilling deep wells and the nature of the interbedded and interlayered basalt flows which make locating the lower most permeable zone difficult. For the purposes of these calculations a saturated thickness of 250 feet was assumed.

By the Butler equation r_{rp} ranges from 1000 ft to 4200 ft, and for the Neuman equation it ranges from 500 ft to 2100 ft. The horizontal offsets (radial distances) for the pumping tests in the TAN area range from 590 ft to 990 ft. It appears that for most of the pumping tests, it is likely that partial penetration effected the measured drawdowns.

In some cases distance-drawdown data can be corrected for partial penetration according to methods described by Butler (1957) or Neuman (1975). However, these corrections cannot be made unless the aquifer parameters are well defined, including the ratio of the horizontal to vertical permeability and the thickness of the saturated aquifer. Because of the difficulties and uncertainties involved with determining these aquifer parameters, the collected pumping test data will be interpreted using standard methods. Correcting for the effects of partial penetration with incomplete or assumed geometric factors might introduce more error into the analysis than original effects of partial penetration.

Figure A1A

TAN-1 PUMPING TEST

Neuman-Type Curve Method

$Q = 1{,}050$ gpm

$= 2.02 \times 10^5\ ft^3/day$

TAN-1 PUMPED WELL

DRAWDOWN

$W(U_A, \Gamma) = 1.0$

$1/U_A = 10^4$

$ho - h = 0.43$ feet

$t = 2.5$ minutes

$$T = \frac{(2.02 \times 10^5\ ft^3/day)\ (1.0)}{4\pi\ (0.43\ ft)} = 3.74 \times 10^4\ ft^2/day\ (280{,}000\ gpd/ft)$$

RECOVERY

$W(U_A, \Gamma) = 1.0$

$1/U_A = 10^4$

$ho - h = 0.96$ feet

$t = 9$ min

$$T = \frac{(2.02 \times 10^5\ ft^3/day)\ (1.0)}{4\pi\ (0.96\ ft)} = 1.67 \times 10^4\ ft^2/day\ (130{,}000\ gpd/ft)$$

Figure A1A Drawdown and recovery measured in pumped well during pumping test of TAN-1.

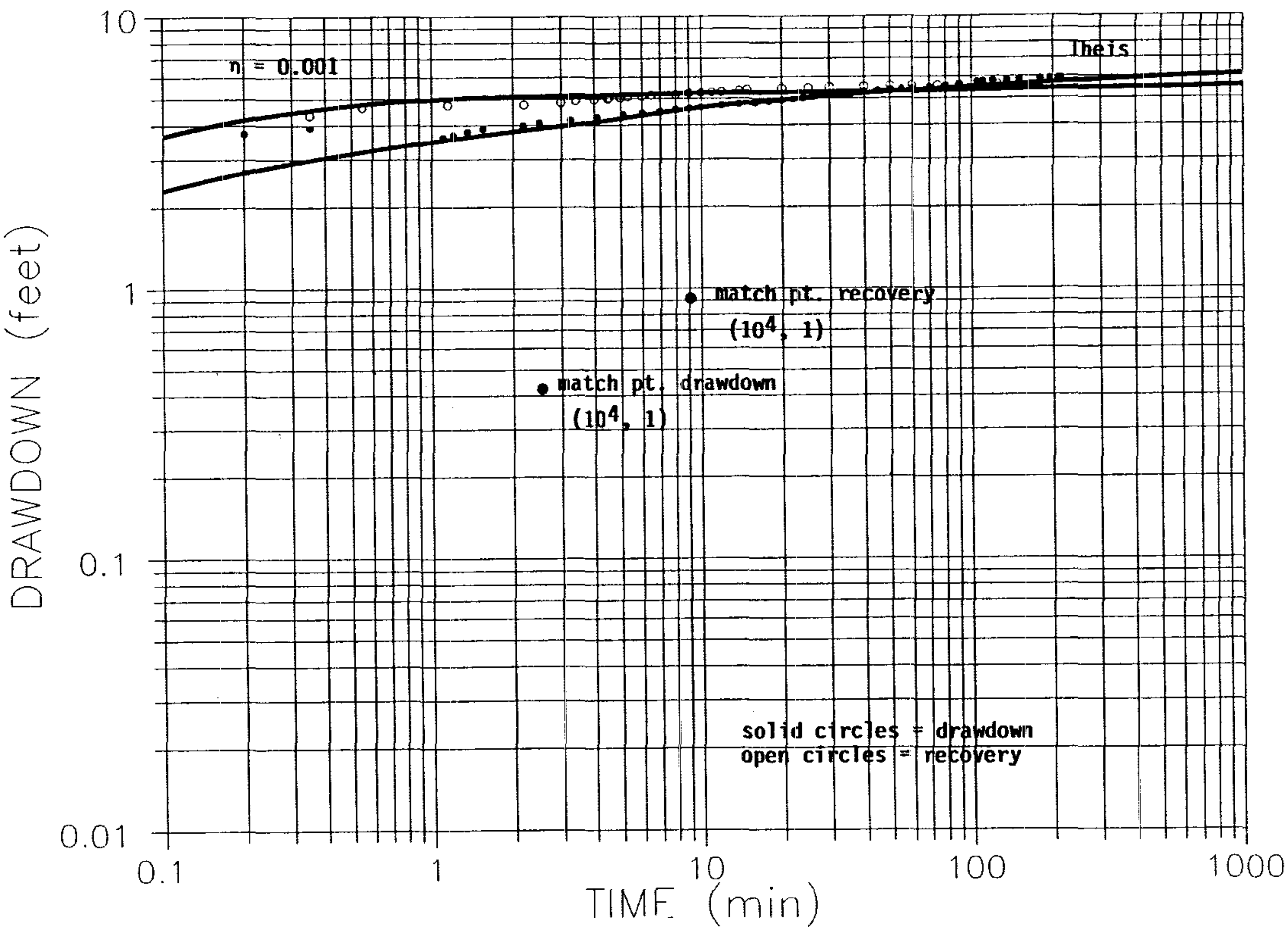


Figure A1B

TAN-1 PUMPING TEST

Jacob Straight-Line Method

$Q = 1{,}050$ gpm

$= 2.02 \times 10^5$ ft^3/day

TAN-1 PUMPED WELL

DRAWDOWN

Δ (ho-h) = 0.99 feet

to = 0.21 min = 1.46×10^{-4} days

$$T = \frac{0.183Q}{\Delta\ (ho\text{-}h)} = \frac{0.183\ (2.02 \times 10^5\ ft^3/day)}{0.99\ ft} = 3.7 \times 10^4\ ft^2/day\ (280{,}000\ gpd/ft)$$

RECOVERY

Δ (ho-h) = 0.92 feet

to = (off graph)

$$T = \frac{0.183Q}{\Delta\ (ho\text{-}h)} = \frac{0.183\ (2.02 \times 10^5\ ft^3/day)}{0.92\ ft} = 4.0 \times 10^4\ ft^3/day\ (300{,}000\ gpd/ft)$$

Figure A1B Drawdown in pumping well during pumping test of TAN-1.

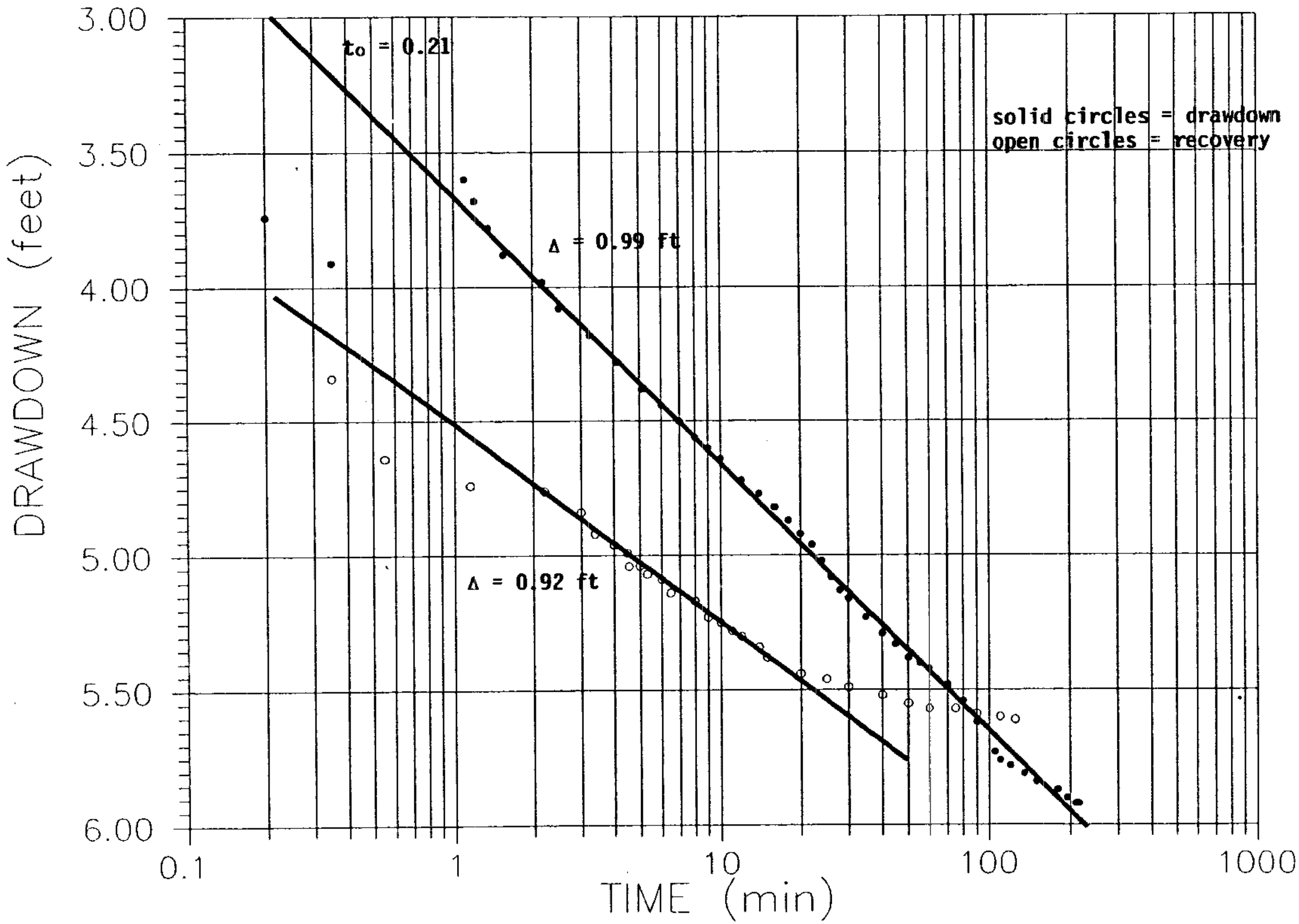


Figure A2A

TAN-1 PUMPING TEST

Neuman-Type Curve Method

OBSERVATION WELL TAN-2

$r = 590$ feet

DRAWDOWN

$W(U_A, \Gamma) = 1.0$

$1/U_A = 1.0$

$h_o - h = 1.3$ feet

$t = 31$ minutes $= 0.0215$ days

$$T = \frac{(2.02 \times 10^5\ ft^3/day)\ (1.0)}{4\pi\ (1.3\ ft)} = 1.20 \times 10^4\ ft^2/day\ (90{,}000\ gpd/ft)$$

$$S = \frac{4TtU_A}{r^2} = \frac{4\ (1.2 \times 10^4\ ft^2/day)\ (0.0215\ days)\ (1.0)}{(590)^2} = 3.1 \times 10^{-3}$$

RECOVERY

$W(U_A, \Gamma) = 1.0$

$1/U_A = 1.0$

$h_o - h = 0.60$ feet

$t = 22$ min $= 0.015$ days

$$T = \frac{(2.02 \times 10^5\ ft^3/day)\ (1.0)}{4\pi\ (0.60\ ft)} = 2.70 \times 10^4\ ft^2/day\ (202{,}000\ gpd/ft)$$

$$S = \frac{4\ (2.7 \times 10^4\ ft^2/day)\ (0.015\ days)\ (1.0)}{(590)^2} = 4.7 \times 10^{-3}$$

Figure A2A Drawdown and recovery measured in Tan-2 during pumping test of TAN-1.

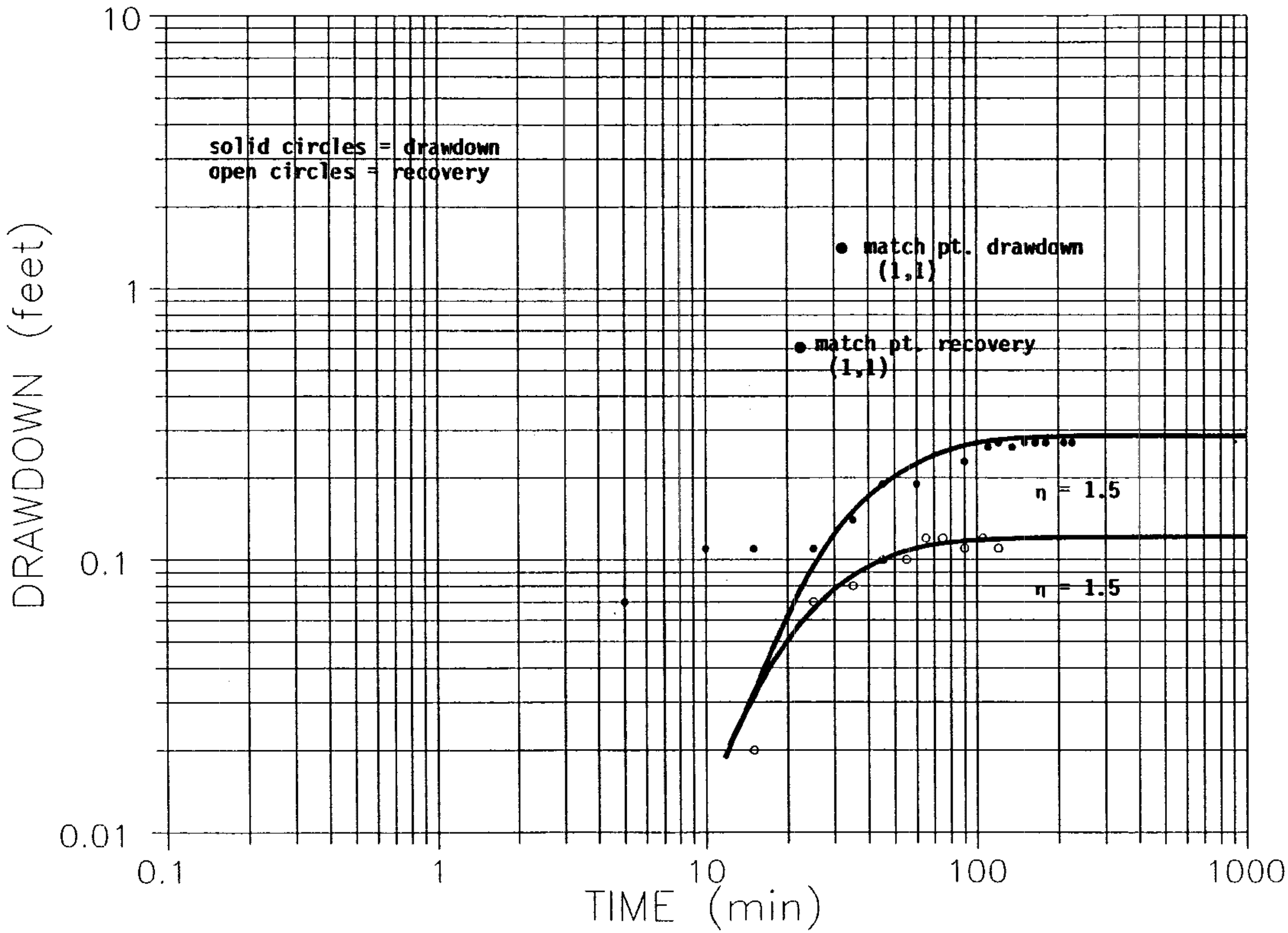


Figure A2B

TAN-1 PUMPING TEST

Jacob Straight-Line Method

OBSERVATION WELL TAN-2

$r = 590$ feet

DRAWDOWN

$\Delta\,(ho-h) = 0.152$ feet

$to = 2.8 \text{ min} = 1.94 \times 10^{-3}$ days

$$T = \frac{0.183Q}{\Delta\,(ho-h)} = \frac{0.183\ (2.02 \times 10^{5}\ ft^{3}/day)}{0.152\ ft} = 2.4 \times 10^{5}\ ft^{2}/day\ (1{,}800{,}000\ gpd/ft)$$

$$S = \frac{2.25\ T\ to}{r^{2}} = \frac{2.25\ (2.4 \times 10^{5}\ ft^{2}/day)\ (1.94 \times 10^{-3}\ day)}{(590\ ft)^{2}} = 3.0 \times 10^{-3}$$

RECOVERY

$\Delta\,(ho-h) = 0.106$ feet

$to = 4.1 \text{ min} = 2.85 \times 10^{-3}$

$$T = \frac{0.183Q}{\Delta\,(ho-h)} = \frac{0.183\ (2.02 \times 10^{5}\ ft^{3}/day)}{0.106\ ft} = 3.5 \times 10^{5}\ ft^{2}/day\ (2{,}600{,}000\ gpd/ft)$$

$$S = \frac{2.25\ T\ to}{r^{2}} = \frac{2.25\ (3.5 \times 10^{5}\ ft^{2}/day)\ (2.85 \times 10^{-3}\ day)}{(590\ ft)^{2}} = 6.4 \times 10^{-3}$$

Figure A2B Drawdown and recovery measured in Tan-2 during pumping test of TAN-1.

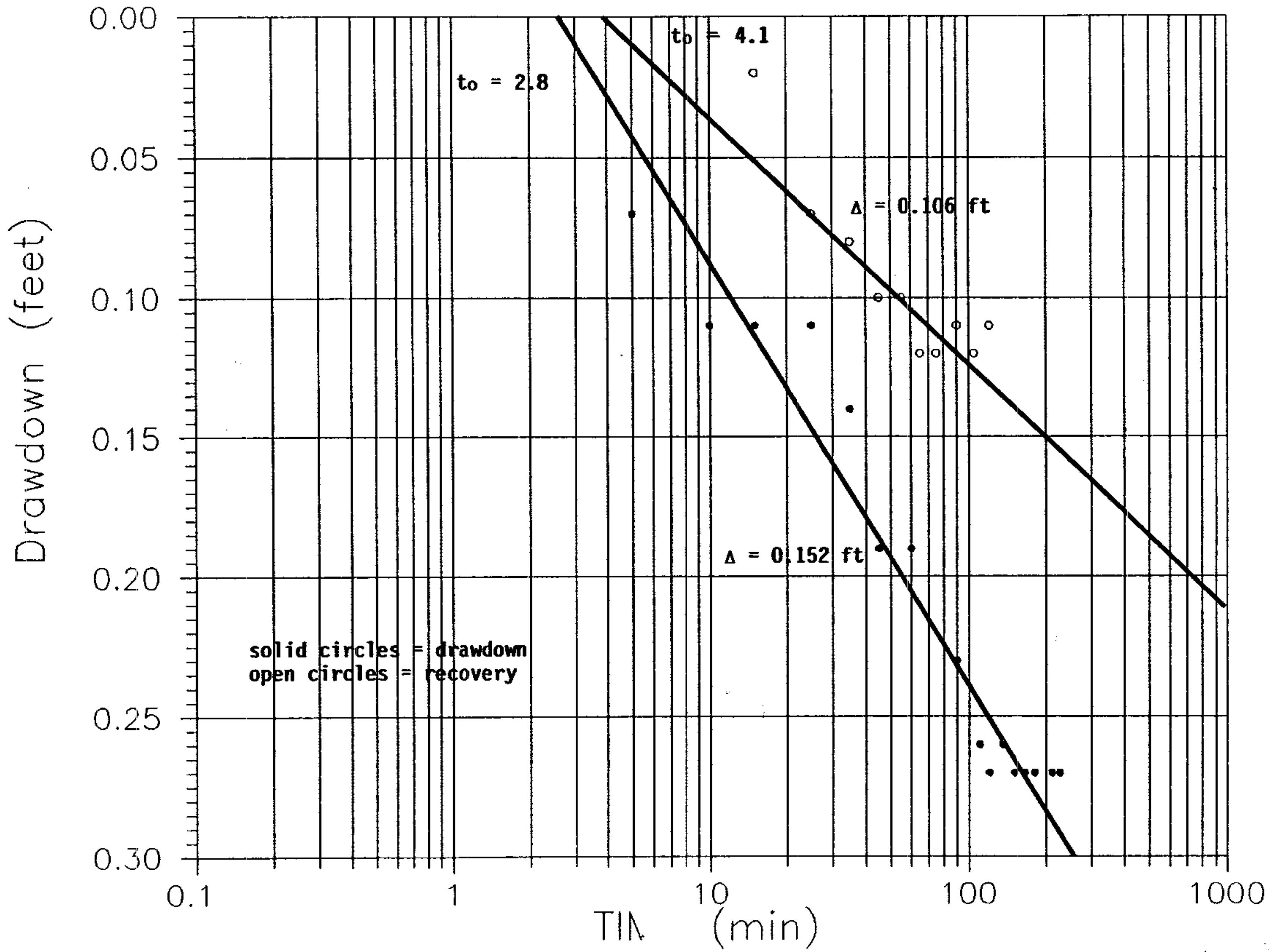


Figure A3A

TAN-1 PUMPING TEST

Neuman-Type Curve Method

OBSERVATION WELL USGS 24

$r = 990$ feet

DRAWDOWN

$W(U_A, \Gamma) = 1.0$

$1/U_A = 1.0$

$ho - h = 0.11$ feet

$t = 13$ minutes $= 0.009$ days

$$T = \frac{(2.02 \times 10^5 \text{ ft}^3/\text{day})\ (1.0)}{4\pi\ (0.11 \text{ ft})} = 1.50 \times 10^5 \text{ ft}^2/\text{day}\ (1{,}100{,}000 \text{ gpd/ft})$$

$$S = \frac{4TtU_A}{r^2} = \frac{4\ (1.5 \times 10^5 \text{ ft}^2/\text{day})\ (0.009 \text{ days})\ (1.0)}{(990)^2} = 5.4 \times 10^{-3}$$

RECOVERY

$W(U_A, \Gamma) = 1.0$

$1/U_A = 1.0$

$ho - h = 0.044$ feet

$t = 4.3$ min $= 3.0 \times 10^{-3}$ days

$$T = \frac{(2.02 \times 10^5 \text{ ft}^3/\text{day})\ (1.0)}{4\pi\ (0.044 \text{ ft})} = 3.70 \times 10^5 \text{ ft}^2/\text{day}\ (2{,}800{,}000 \text{ gpd/ft})$$

$$S = \frac{4\ (3.7 \times 10^5 \text{ ft}^2/\text{day})\ (3.0 \times 10^{-3} \text{ days})\ (1.0)}{(990)^2} = 4.5 \times 10^{-3}$$

Figure A3A Measured drawdown and recovery in USGS 24 during pumping test of TAN-1.

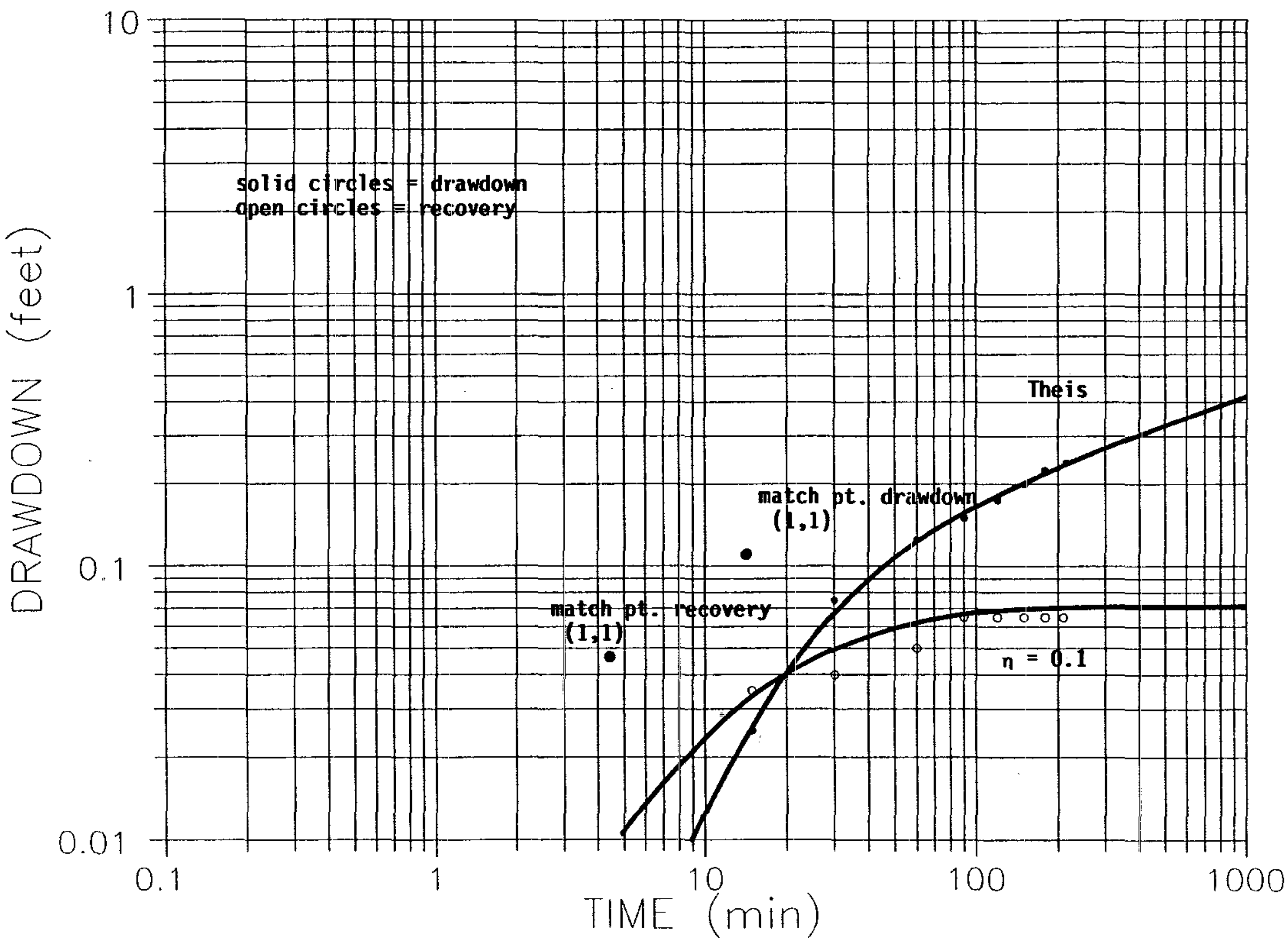


Figure A3B

TAN-1 PUMPING TEST

Jacob Straight-Line Method

OBSERVATION WELL USGS 24

$r = 990$ feet

DRAWDOWN

$\Delta\ (ho-h) = 0.170$ feet

$to = 10.1\ \text{min} = 7.01 \times 10^{-3}$ days

$$T = \frac{0.183Q}{\Delta\ (ho-h)} = \frac{0.183\ (2.02 \times 10^{5}\ ft^{3}/day)}{0.17\ ft} = 2.1 \times 10^{5}\ ft^{2}/day\ (1{,}600{,}000\ gpd/ft)$$

$$S = \frac{2.25\ (2.1 \times 10^{5}\ ft^{2}/day)\ (7.01 \times 10^{-3}\ day)}{(990\ ft)^{2}} = 3.4 \times 10^{-3}$$

RECOVERY

Inconsistent data.

Figure A3B Measured drawdown and recovery in USGS 24 during pumping test of TAN-1.

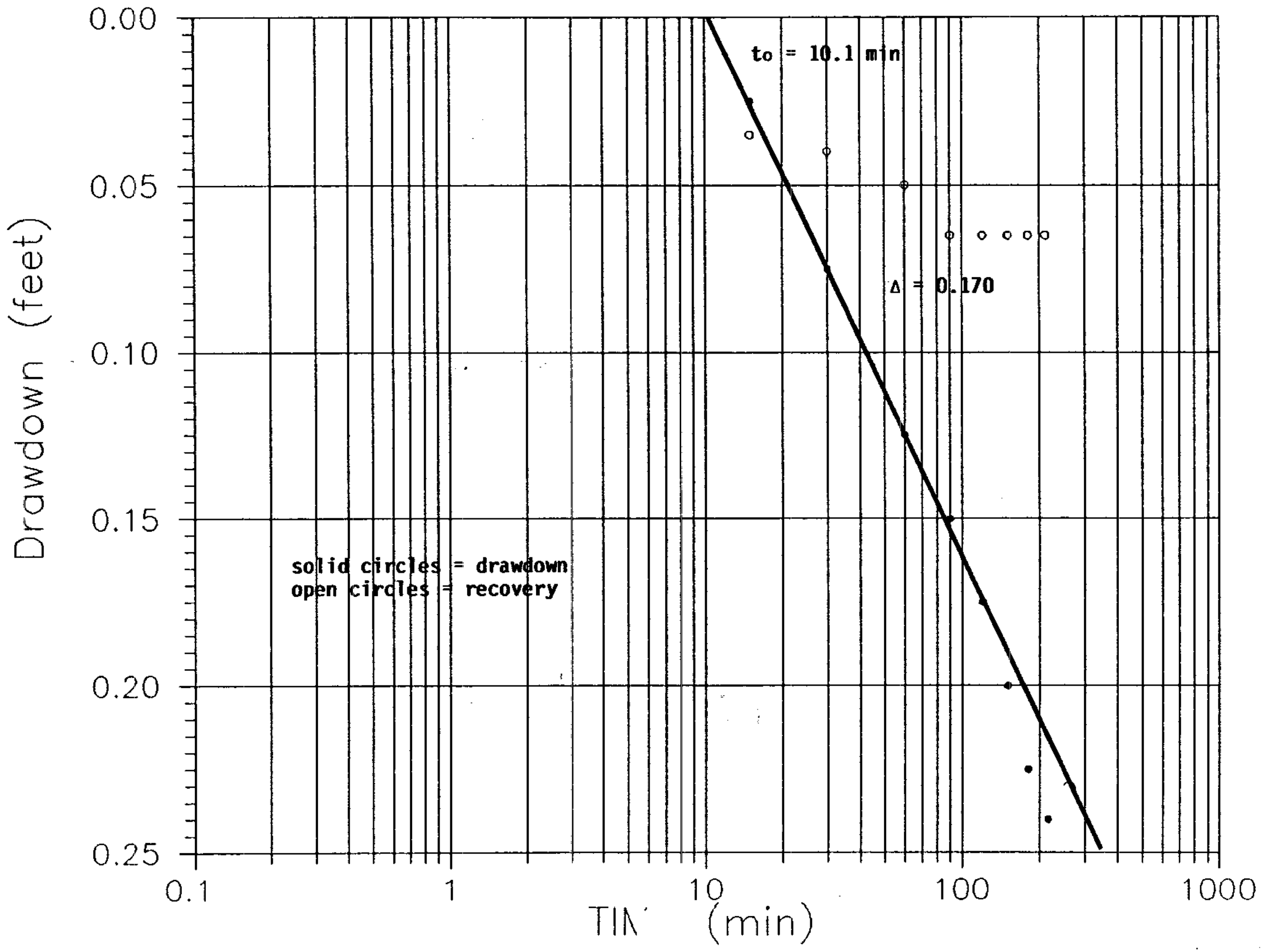


Figure A4A

TAN-2 PUMPING TEST

Neuman-Type Curve Method

$Q = 1,010$ gpm
$= 1.94 \times 10^5$ ft^3/day

TAN-2 PUMPED WELL

DRAWDOWN AND RECOVERY

$W(U_A, \Gamma) = 1.0$
$1/U_A = 10^4$
$h_o - h = 1.3$ feet
$t = 21$ minutes $= 1.46 \times 10^{-2}$ days

$$T = \frac{(1.94 \times 10^5 \text{ ft}^3/\text{day})\ (1.0)}{4\pi\ (1.3 \text{ feet})} = 1.2 \times 10^4 \text{ ft}^2/\text{day}\ (90{,}000 \text{ gpd/ft})$$

Figure A4A Drawdown and recovery measured in pumped well during pumping test of TAN-2.

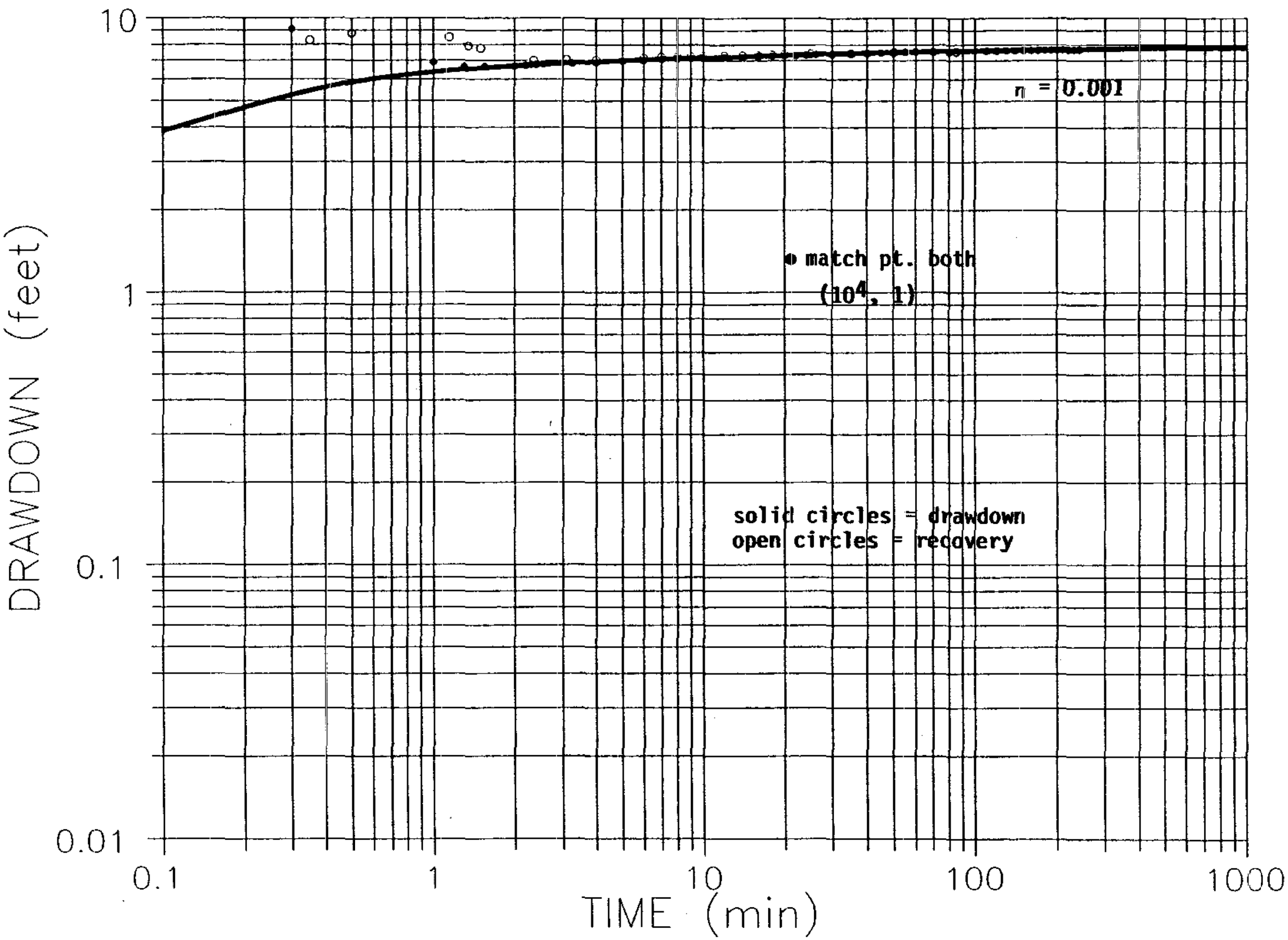


Figure A4B

TAN-2 PUMPING TEST

Jacob Straight-Line Method

$Q = 1{,}010$ gpm

$= 1.94 \times 10^5\ ft^3/day$

TAN-2 PUMPED WELL

DRAWDOWN Slope No. 1

Δ (ho-h) = 0.55 feet

to = N/A

$$T = \frac{0.183Q}{\Delta\ (ho-h)} = \frac{0.183\ (1.94 \times 10^5\ ft^3/day)}{0.55\ ft} = 6.4 \times 10^4\ ft^2/day\ (480{,}000\ gpd/ft)$$

RECOVERY

Δ (ho-h) = 0.40 feet

to = N/A

$$T = \frac{0.183Q}{\Delta\ (ho-h)} = \frac{0.183\ (1.94 \times 10^5\ ft^3/day)}{0.40\ ft} = 8.8 \times 10^4\ ft^2/day\ (660{,}000\ gpd/ft)$$

DRAWDOWN AND RECOVERY Slope No. 2

Δ (ho-h) = 0.20 feet

$$T = \frac{0.183Q}{\Delta\ (ho-h)} = \frac{0.183\ (1.94 \times 10^5\ ft^3/day)}{0.20\ ft} = 1.8 \times 10^5\ ft^2/day\ (1{,}300{,}000\ gpd/ft)$$

Figure A4B Drawdown and recovery measured in pumped well during pumping test of TAN-2.

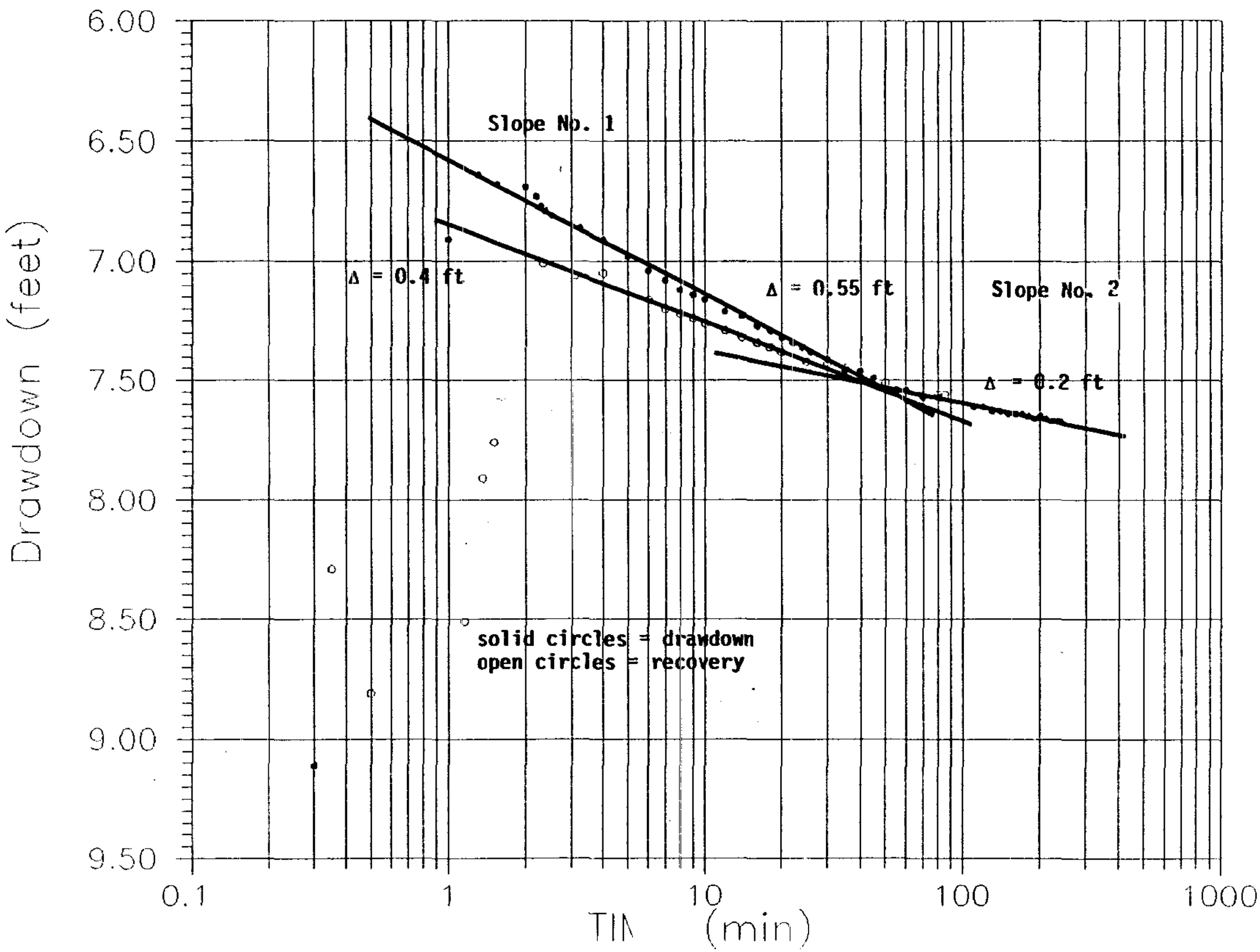


Figure A5A

TAN-2 PUMPING TEST

Neuman-Type Curve Method

OBSERVATION WELL USGS 24

$r = 920$ feet

DRAWDOWN

$W(U_A, \Gamma) = 10$

$1/U_A = 10.0$

$ho - h = 0.43$ feet

$t = 11$ minutes $= 7.64 \times 10^{-3}$ days

$$T = \frac{(1.94 \times 10^5 \text{ ft}^3/\text{day})\ (10)}{4\pi\ (0.43 \text{ ft})} = 3.50 \times 10^5 \text{ ft}^2/\text{day}\ (2{,}600{,}000 \text{ gpd/ft})$$

$$S = \frac{4\ (3.5 \times 10^5 \text{ ft}^2/\text{day})\ (7.64 \times 10^{-3} \text{ days})\ (10)}{(920)^2} = 1.3 \times 10^{-3}$$

RECOVERY

$W(U_A, \Gamma) = 10$

$1/U_A = 1.0$

$ho - h = 2.10$ feet

$t = 85$ min $= 5.9 \times 10^{-2}$ days

$$T = \frac{(1.94 \times 10^5 \text{ ft}^3/\text{day})\ (10)}{4\pi\ (2.10 \text{ ft})} = 7.40 \times 10^4 \text{ ft}^2/\text{day}\ (550{,}000 \text{ gpd/ft})$$

$$S = \frac{4\ (7.4 \times 10^4 \text{ ft}^2/\text{day})\ (5.9 \times 10^{-2} \text{ days})\ (1.0)}{(920)^2} = 2.0 \times 10^{-2}$$

Figure A5A Measured drawdown and recovery in USGS 24 during pumpnig test of TAN-2.

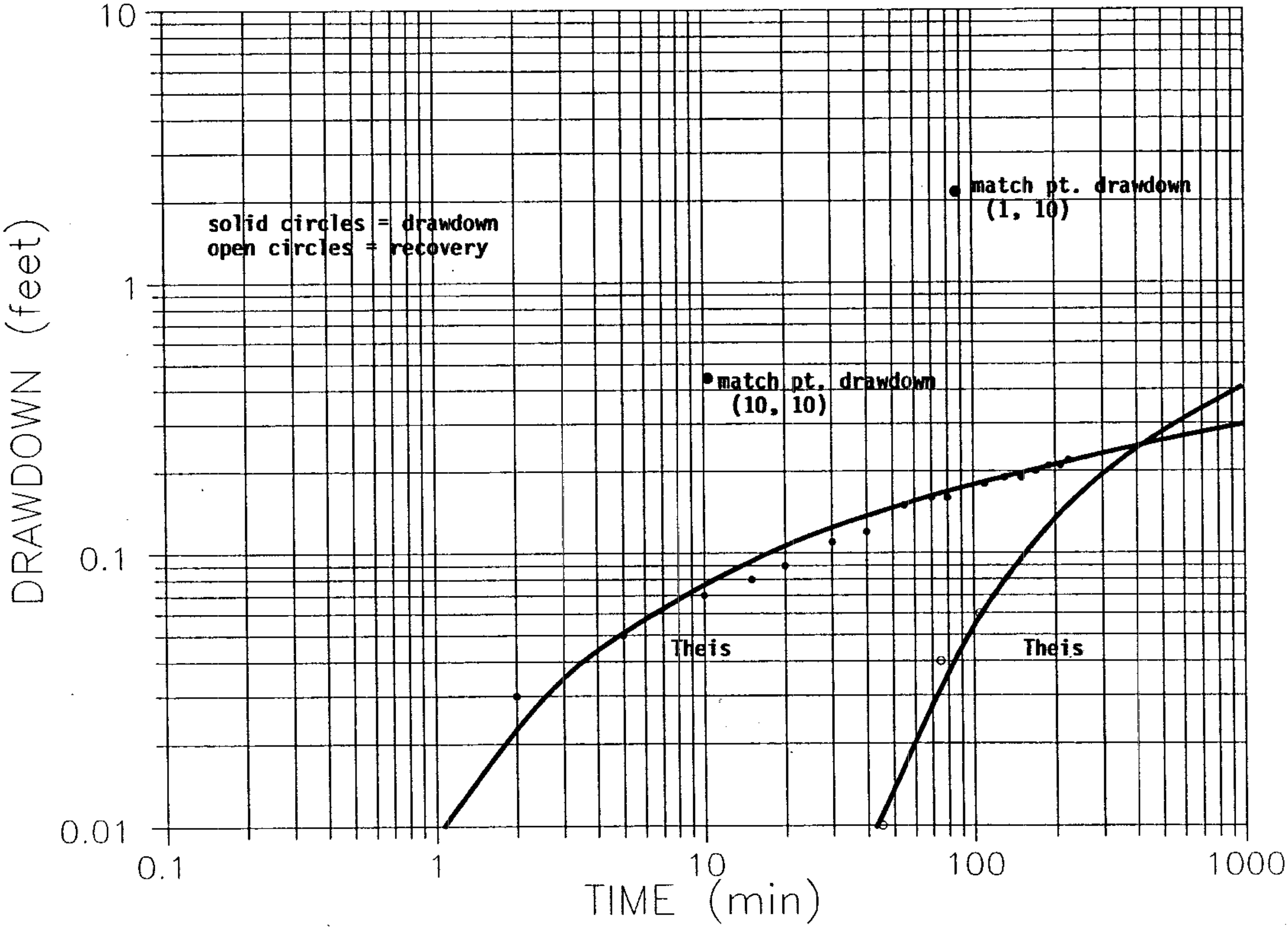


Figure A5B

TAN-2 PUMPING TEST

Jacob Straight-Line Method

OBSERVATION WELL USGS 24

$r = 920$ feet

DRAWDOWN

Δ (ho-h) = 0.121 feet

to = 3.4 min = 2.36×10^{-3} days

$$T = \frac{0.183Q}{\Delta\,(ho\text{-}h)} = \frac{0.183\ (1.94 \times 10^{5}\ ft^{3}/day)}{0.121\ ft} = 2.9 \times 10^{5}\ ft^{2}/day\ (2{,}200{,}000\ gpd/ft)$$

$$S = \frac{2.25\ T\ to}{r^{2}} = \frac{2.25\ (2.9 \times 10^{5}\ ft^{2}/day)\ (2.36 \times 10^{-3}\ day)}{(920\ ft)^{2}} = 1.82 \times 10^{-3}$$

RECOVERY

Δ (ho-h) = 0.135 feet

to = 28 min = 1.94×10^{-2}

$$T = \frac{0.183Q}{\Delta\,(ho\text{-}h)} = \frac{0.183\ (1.94 \times 10^{5}\ ft^{3}/day)}{0.135\ ft} = 2.6 \times 10^{5}\ ft^{2}/day\ (1{,}900{,}000\ gpd/ft)$$

$$S = \frac{2.25\ T\ to}{r^{2}} = \frac{2.25\ (2.6 \times 10^{5}\ ft^{2}/day)\ (1.94 \times 10^{-2}\ day)}{(920\ ft)^{2}} = 1.35 \times 10^{-2}$$

Figure A5B Measured drawdown and recovery in USGS 24 during pumping test of TAN-2.

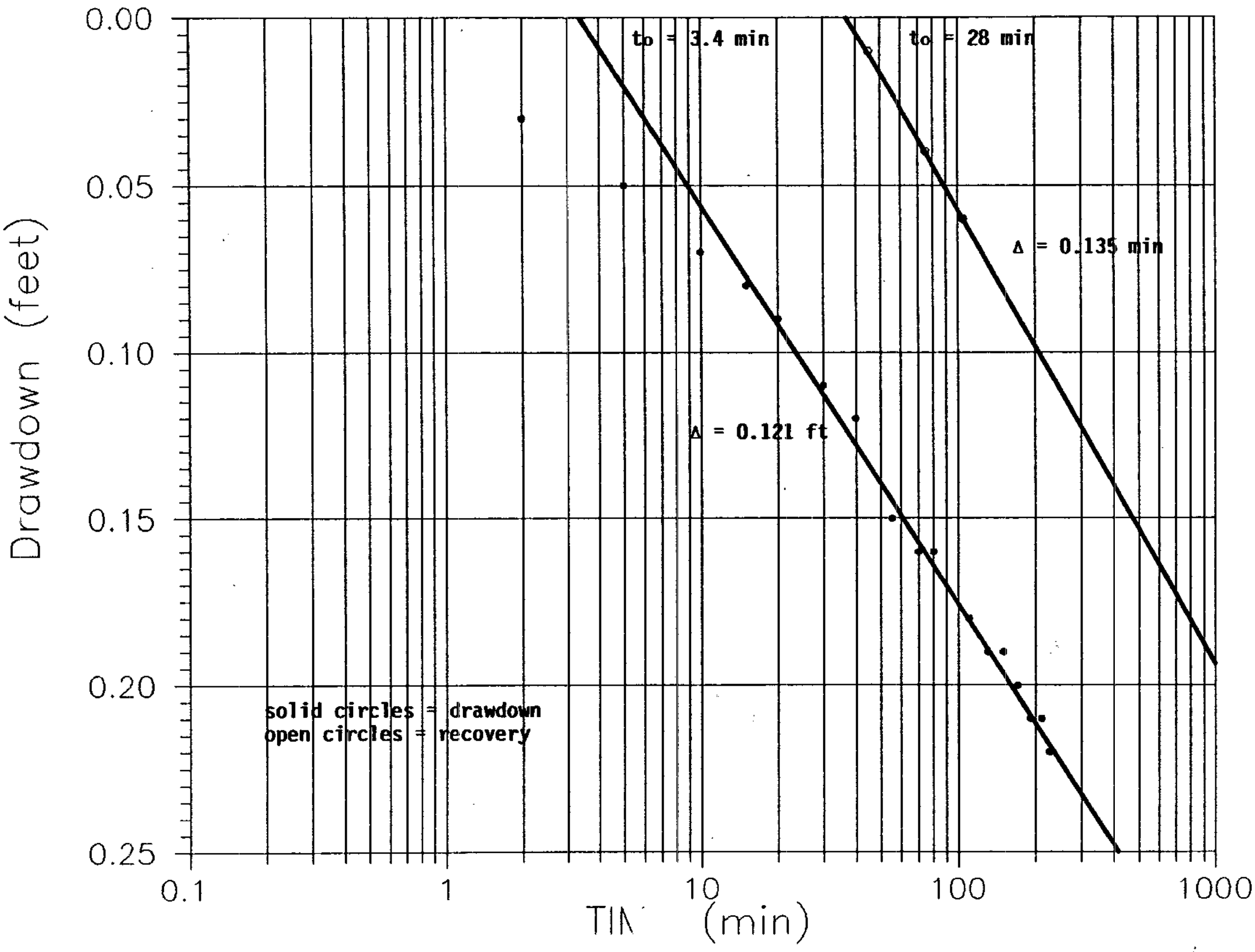


Figure A6A

TAN-2 PUMPING TEST

Neuman-Type Curve Method

OBSERVATION WELL TAN-1

$r = 590$ feet

DRAWDOWN AND RECOVERY

$W(U_A, \Gamma) = 1.0$

$1/U_A = 1.0$

$h_o - h = 0.051$ feet

$t = 2.2$ minutes $= 1.53 \times 10^{-3}$ days

$$T = \frac{(1.94 \times 10^5 \text{ ft}^3/\text{day})\ (1.0)}{4\pi\ (0.051 \text{ ft})} = 3.03 \times 10^5 \text{ ft}^2/\text{day}\ (2{,}300{,}000 \text{ gpd/ft})$$

$$S = \frac{4\ (3.03 \times 10^5 \text{ ft}^2/\text{day})\ (1.53 \times 10^{-3} \text{ days})\ (1.0)}{(590)^2} = 5.3 \times 10^{-3}$$

Figure A6A Drawdown and recovery measured in TAN-1 during pumping test of TAN-2.

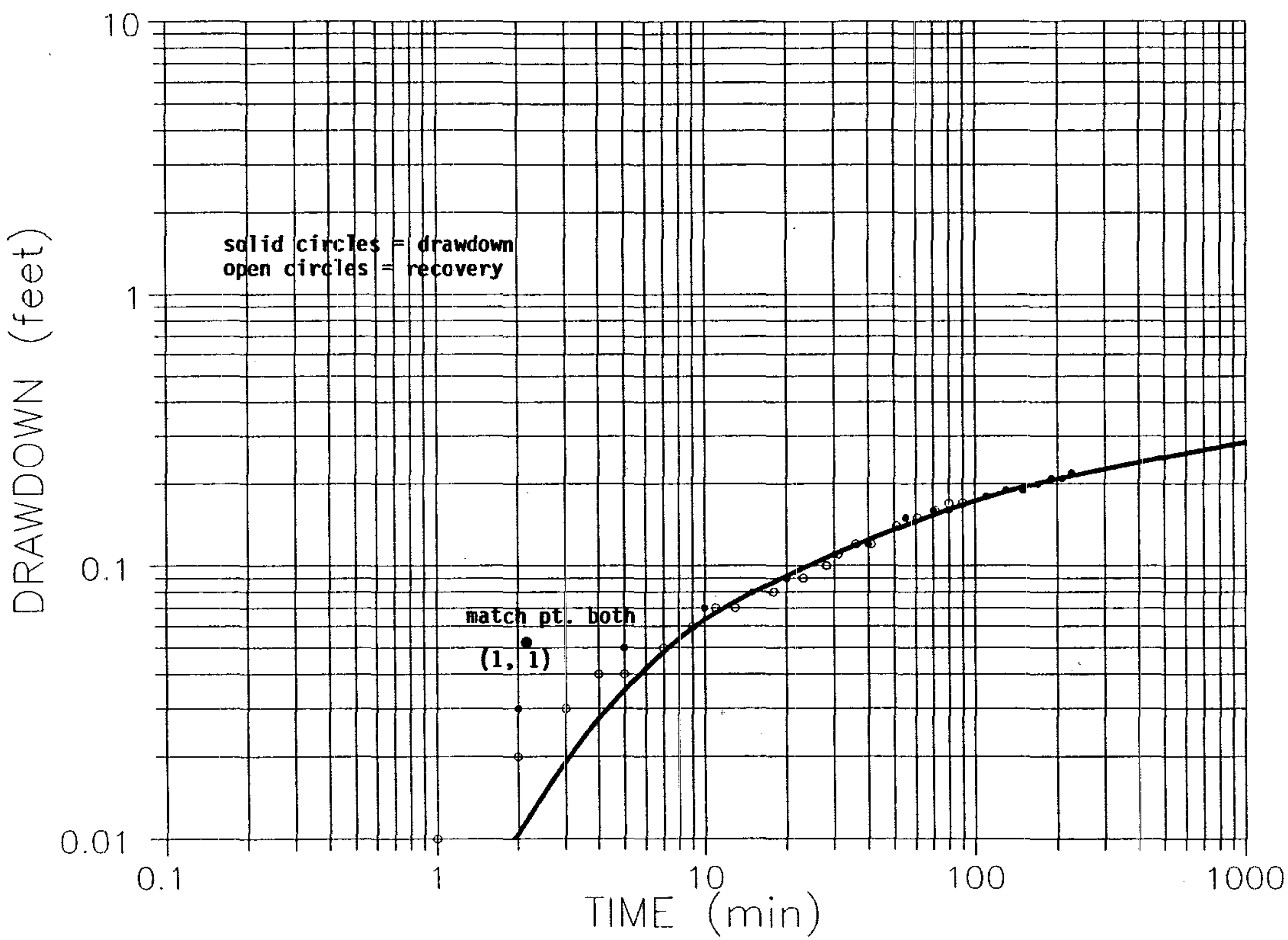


Figure A6B

TAN-2 PUMPING TEST

Jacob Straight-Line Method

OBSERVATION WELL

r = 590 feet

DRAWDOWN AND RECOVERY

Δ (ho-h) = 0.123 feet

to = 3.4 min = 2.36×10^{-3} days

$$T = \frac{0.183Q}{\Delta (ho-h)} = \frac{0.183\ (1.94\ 10^{5}\ ft^{3}/day)}{0.123\ ft} = 2.9 \times 10^{5}\ ft^{2}/day\ (2{,}200{,}000\ gpd/ft)$$

$$S = \frac{2.25\ T\ to}{r^{2}} = \frac{2.25\ (2.9 \times 10^{5}\ ft^{2}/day)\ (2.36 \times 10^{-3}\ day)}{(590\ ft)^{2}} = 4.4 \times 10^{-3}$$

Figure A6B Drawdown and recovery measured in TAN−1 during pumping test of TAN−2.

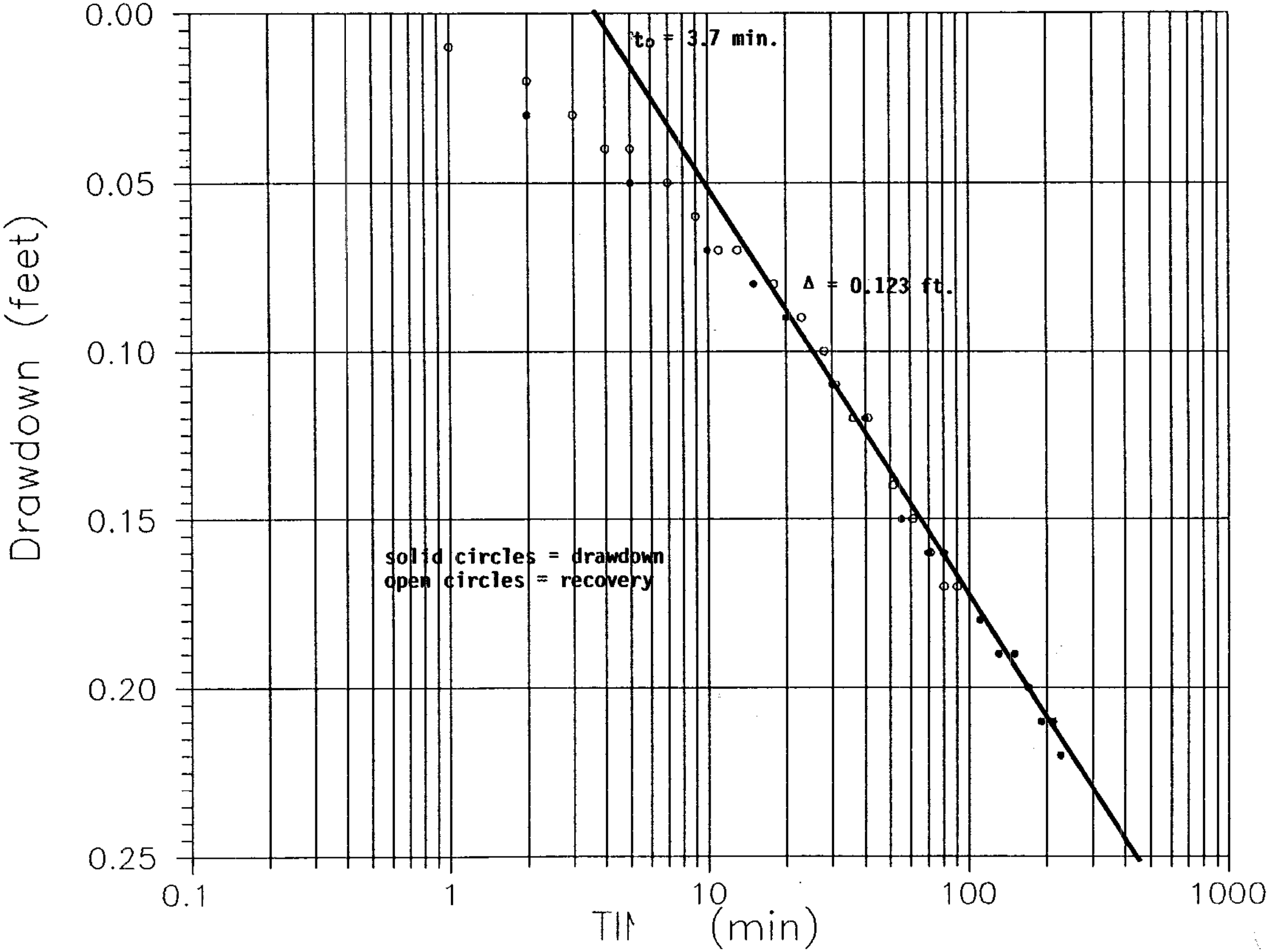


Figure A7A

IET-DISP PUMPING TEST

Neuman-Type Curve Method

$Q = 19.99$ gpm

$= 3848.1\ ft^3/day$

IET-DISP PUMPED WELL

DRAWDOWN

$W(U_A, \Gamma) = 10^{-1}$

$1/U_A = 10.0$

$ho - h = 0.084$ feet

$t = 1.8$ minutes

$$T = \frac{(3.8 \times 10^3\ ft^3/day)\ (10^{-1})}{4\pi\ (0.084\ ft)} = 364.5\ ft^2/day\ (2{,}700\ gpd/ft)$$

RECOVERY

$W(U_A, \Gamma) = 10^{-1}$

$1/U_A = 10.0$

$ho - h = 0.016$ feet

$t = 1.6$ minutes

$$T = \frac{(3.8 \times 10^3\ ft^3/day)\ (10^{-1})}{4\pi\ (0.16\ ft)} = 189.0\ ft^2/day\ (1{,}400\ gpd/ft)$$

Figure A7A Drawdown and recovery measured in pumped well during pumping test of IET-1. **(IET-DISP)**

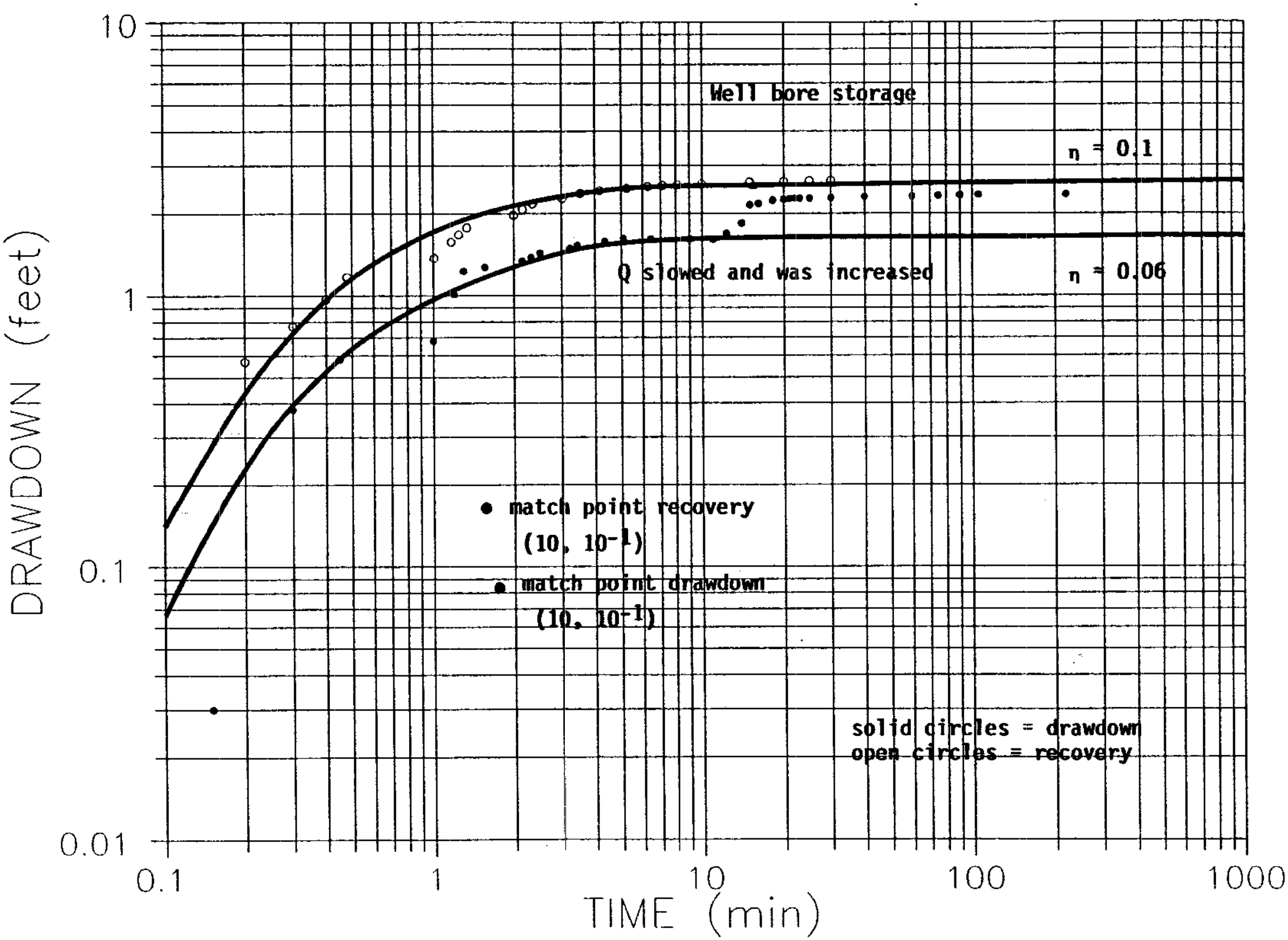


Figure A7B

IET-DISP PUMPING TEST

Jacob Straight-Line Method

Initial Slope

$Q = 19.99$ gpm

$= 3848.1\ ft^3/day$

IET-DISP PUMPED WELL

DRAWDOWN

$\Delta\ (ho-h) = 1.04$ feet

to = N/A

$$T = \frac{0.183Q}{\Delta\ (ho-h)} = \frac{0.183\ (3848.1\ ft^3/day)}{1.04\ ft} = 677.1\ ft^2/day\ (5,100\ gpd/ft)$$

RECOVERY

$\Delta\ (ho-h) = 1.50$ feet

to = N/A

$$T = \frac{0.183Q}{\Delta\ (ho-h)} = \frac{0.183\ (3848.1\ ft^3/day)}{1.50\ ft} = 469.5\ ft^2/day\ (3,500\ gpd/ft)$$

Figure A7B

IET-DISP PUMPING TEST

Jacob Straight-Line Method

Second Slope

$Q = 19.99$ gpm

$= 3848.1\ ft^3/day$

IET-DISP PUMPED WELL

DRAWDOWN

$\Delta\ (ho\text{-}h) = 0.1$ feet

to = N/A

$$T = \frac{0.183Q}{\Delta\ (ho\text{-}h)} = \frac{0.183\ (3848.1\ ft^3/day)}{0.1\ ft} = 7042.0\ ft^2/day\ (53{,}000\ gpd/ft)$$

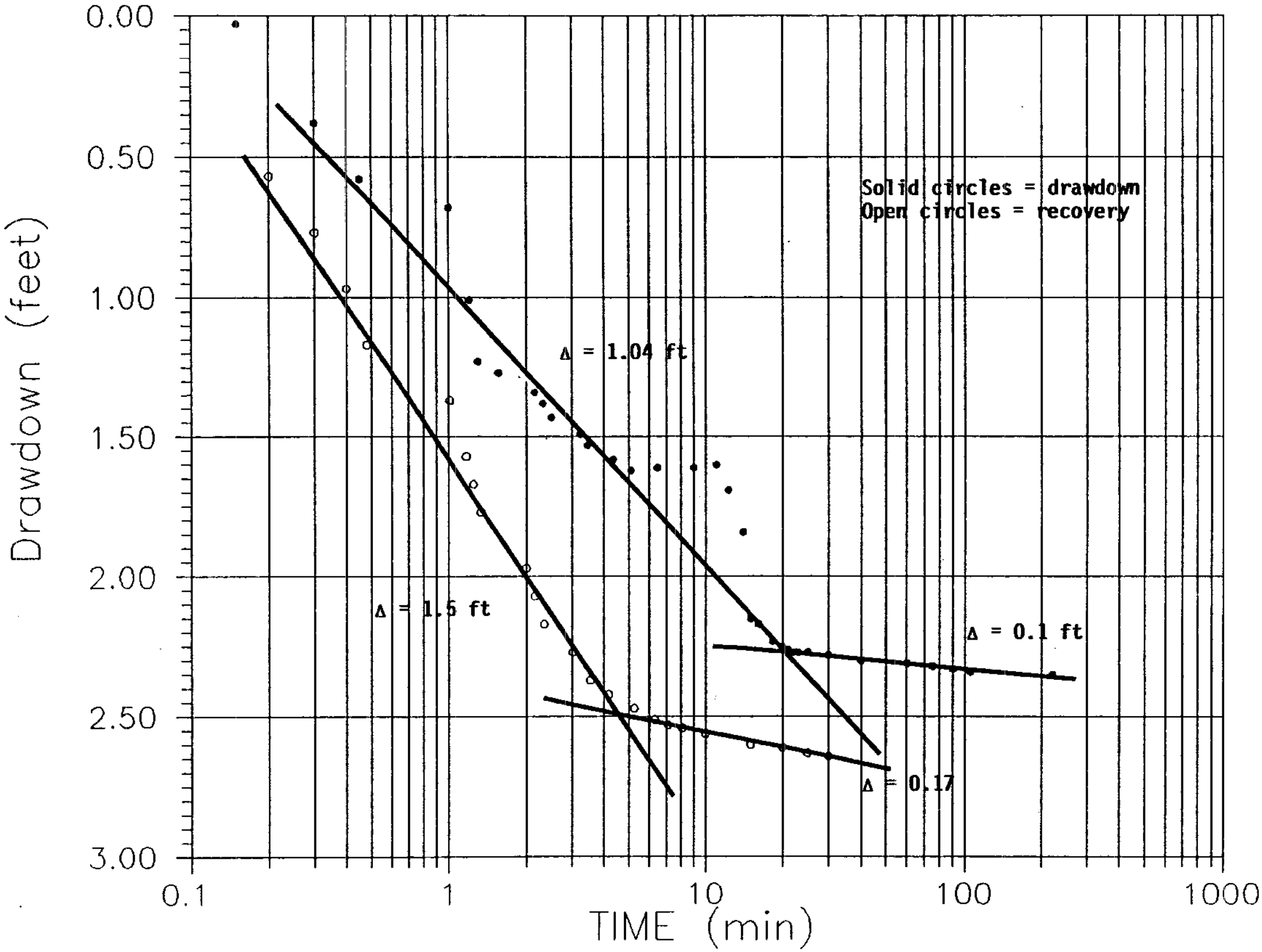
RECOVERY

$\Delta\ (ho\text{-}h) = 0.17$ feet

to = N/A

$$T = \frac{0.183Q}{\Delta\ (ho\text{-}h)} = \frac{0.183\ (3848.1\ ft^3/day)}{0.17\ ft} = 4142.4\ ft^2/day\ (31{,}000\ gpd/ft)$$

Figure A7B Drawdown and recovery measured in pumped well during pumping test of IET-1. (IET-DISP)



IET-DISP

Figure A7B

Well Bore Storage Calculations

$$Tc = \frac{0.6\ (dc^2 - dp^2)}{Q/s}$$

Where:

tc = time, in minutes, when casing storage effect becomes negligible

dc = inside diameter of well casing, in inches

dp = outside diameter of pump column pipe, in inches

Q/s = specific capacity of the well in gpm/ft of drawdown at time tc

dc = 12 in.
dp = 2 in.
Q = 19.99 gpm
s = initial assumption = 2 ft.

by iteration:

Recovery

tc	s	s from recovery graph
8.40	2	2.55
10.7	2.55	2.6
10.9	2.6	2.6

Drawdown

tc	s	s from drawdown graph
10.5	2.5	2.15
9.0	2.15	1.9
8.0	1.9	1.85
7.8	1.85	1.84

tc (recovery) = 10.9 min.
tc (drawdown) = 7.8 min.*

* Drawdown curve and discharge rate were effected by a decrease in pumping rate (Figure A7B). Therefore, tc for the drawdown curve is probably in error.

The Tc (recovery) value suggests that the casing storage effect would have become negligible after approximately 11 minutes. Thus, the initial slope provides an erroneous T value and any predictions of the wells' performance should be based on the T value, calculated on the basis of the latter part of the curve. The transmissivity calculations are on the following page.

Figure A8A

TSF-INJ PUMPING TEST

Neuman-Type Curve Method

$Q = 19.7$ gpm

$= 3970\ ft^3/day$

TSF-INJ PUMPED WELL

DRAWDOWN

$W\ (U_A,\ \Gamma) = 10^{-1}$

$1/U_A = 1.0$

ho - h = 1.2 feet

t = 2.3 minutes

$$T = \frac{(3.79 \times 10^3\ ft^3/day)\ (10^{-1})}{4\pi\ (1.2\ ft)} = 25.1\ ft^2/day\ (190\ gpd/ft)$$

RECOVERY

$W\ (U_A,\ \Gamma) = 1.0$

$1/U_A = 1.0$

ho - h = 5.0 feet

t = 0.44 minutes

$$T = \frac{(3.79 \times 10^3\ ft^3/day)\ (1.0)}{4\pi\ (5.0\ ft)} = 60.3\ ft^2/day\ (450\ gpd/ft)$$

Figure A8A Drawdown and recovery measured in pumped well during pumping test of ANP-3. (TSF-INJ)

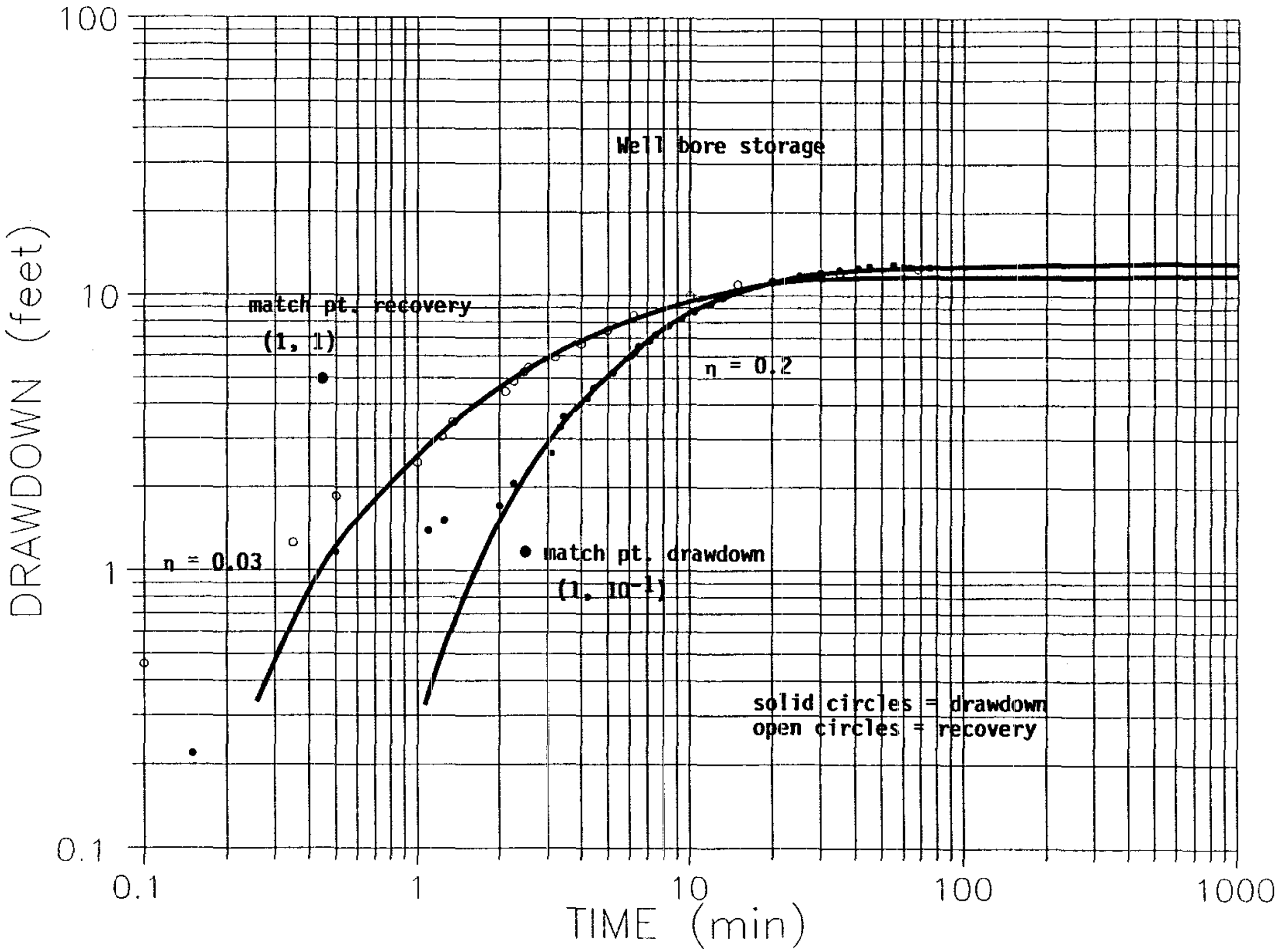


Figure A8B

TSF-INJ PUMPING TEST

Jacob Straight-Line Method

Initial Slope

$Q = 19.70$ gpm

$= 3970.0\ ft^3/day$

TSF-INJ PUMPED WELL

DRAWDOWN

$\Delta\ (ho-h) = 11$ feet

to = N/A

$$T = \frac{0.183Q}{\Delta\ (ho-h)} = \frac{0.183\ (3970.0\ ft^3/day)}{11\ ft} = 66.5\ ft^2/day\ (500\ gpd/ft)$$

RECOVERY

$\Delta\ (ho-h) = 7.6$ feet

to = N/A

$$T = \frac{0.183Q}{\Delta\ (ho-h)} = \frac{0.183\ (3970.0\ ft^3/day)}{7.6\ ft} = 95.6\ ft^2/day\ (700\ gpd/ft)$$

Figure A8B

TSF-INJ PUMPING TEST

Jacob Straight-Line Method

Second Slope

$Q = 19.70$ gpm

$= 3970.0 \ ft^3/day$

TSF-INJ PUMPED WELL

DRAWDOWN

Δ (ho-h) = 1.8 feet

to = N/A

$$T = \frac{0.183Q}{\Delta\ (ho-h)} = \frac{0.183\ (3970.0\ ft^3/day)}{1.8\ ft} = 403.6\ ft^2/day\ (3{,}000\ gpd/ft)$$

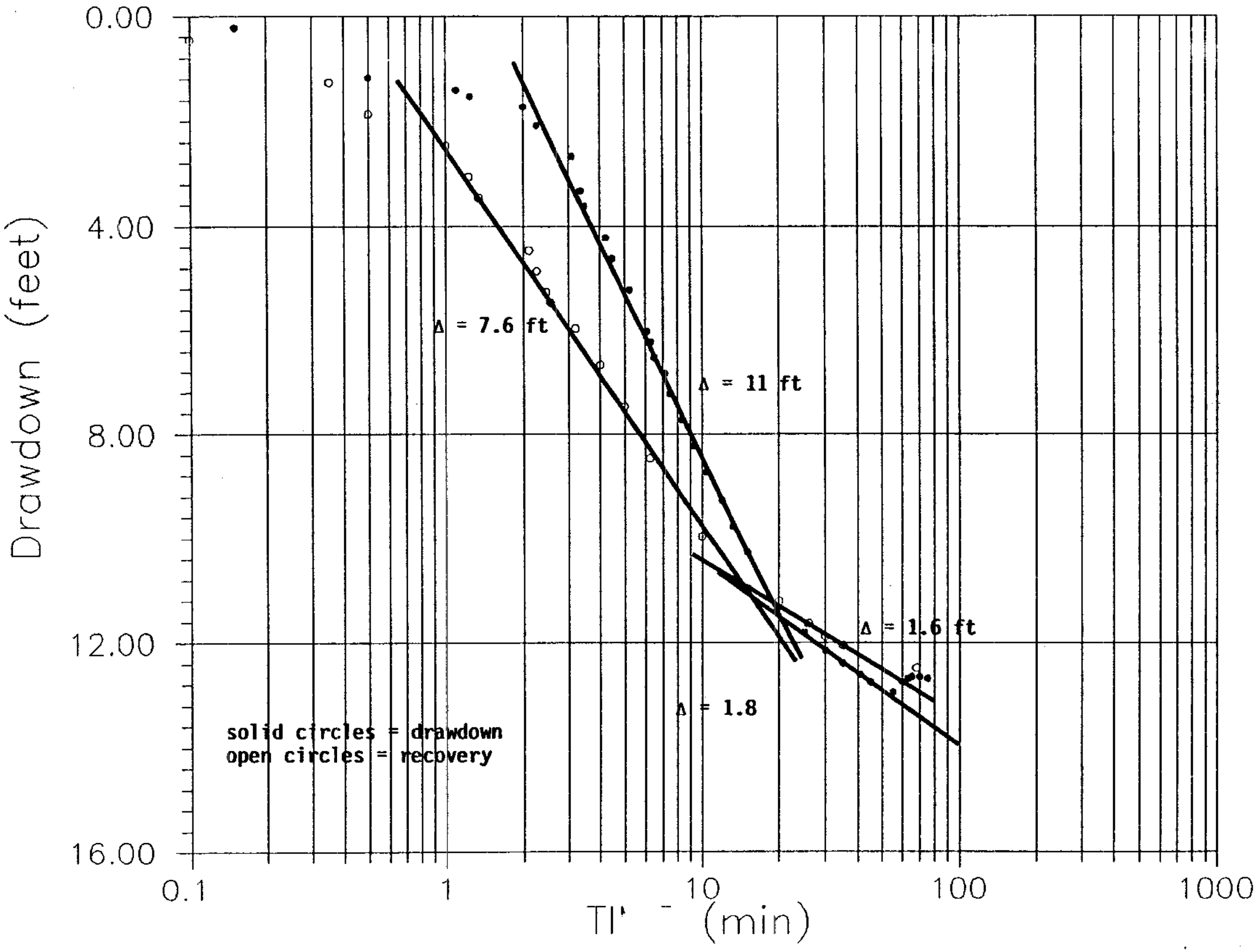
RECOVERY

Δ (ho-h) = 1.6 feet

to = N/A

$$T = \frac{0.183Q}{\Delta\ (ho-h)} = \frac{0.183\ (3970.0\ ft^3/day)}{1.6\ ft} = 454.1\ ft^2/day\ (3{,}400\ gpd/ft)$$

Figure A8B Drawdown and recovery measured in pumped well during pumping test of ANP-3. (TSF-INJ)



TSF-INJ

Figure A8B

Well Bore Storage Calculations

$$Tc = \frac{0.6\ (dc^2 - dp^2)}{Q/s}$$

Where:

tc = time, in minutes, when casing storage effect becomes negligible

dc = inside diameter of well casing, in inches

dp = outside diameter of pump column pipe, in inches

Q/s = specific capacity of the well in gpm/ft of drawdown at time tc

dc = 12 in.
dp = 2 in.
Q = 19.7 gpm
s = initial assumption = 10 ft.

by iteration:

Recovery

tc	s	s from recovery graph
42.6	10	12.2
52.0	12.2	13.3
52.4	12.3	12.3

Drawdown

tc	s	s from drawdown graph
42.6	10	12.3
52.4	12.3	12.4
52.9	12.4	12.4
7.8	1.85	1.84

tc (recovery) = 52.4 min.
tc (drawdown) = 52.9 min.

The Tc values suggest that the casing storage effect would have become negligible after approximately 52 minutes. Thus, the initial slope provides an erroneous T value and any predictions of the wells' performance should be based on the T value, calculated on the basis of the latter part of the curve. The transmissivity calculations are on the following page.

APPENDIX B

AQUIFER TEST FIELD DATA SHEETS

FOR 1987 PUMPING TESTS

AQUIFER TEST FIELD DATA SHEET

X Pumped well TAN #1 Building 612 Page 1 of 5

___ Observation well No. ___

Owner: DOE

Location: TAN Building 612
435056 112420801
06N 31E 13acd1
Circular Butte 7.5'

Observers: LB

Measuring point is Top of 1" coupler which is 1.45 feet above below surface. Pump house floor

Static water level 204.22 feet below land surface.

Distance to pumped well ______ feet.

Discharge rate of pumped well 1050 gpm (gallons per minute).

Total number of observation wells 2 - USGS 24 + TAN #2

Date	Clock time	Elapsed time since pumping started / stopped (minutes)		Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11/17/87	1100	0		204.22	0	Pump ON
	110020	.20	.33	207.96	3.74	
	110035	.35	.58	208.13	3.91	
	110110	1.10	1.16	207.82	3.60	
	110120	1.20	1.33	207.90	3.68	
	110135	1.35	1.58	208.00	3.78	
	110155	1.55	1.93	208.10	3.88	
	110218	2.18	2.30	208.20	3.98	
	110250	2.50	2.83	208.30	4.08	
	110325	3.25	3.42	208.40	4.18	
	110410	4.10	4.16	208.50	4.28	
	110512	5.12	5.20	208.60	4.38	
	110600	6.0	6.0	208.66	4.44	

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well TAN # 1 Building 612 Page 2 of 5

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11/17/87	1107	7.0	208.72	4.50	
	1108	8.0	208.78	4.56	
	1109	9.0	208.82	4.60	
	1110	10.0	208.86	4.64	
	1112	12.0	208.94	4.72	
	1114	14.0	208.99	4.77	
	1116	16.0	209.04	4.82	
	1118	18.0	209.09	4.87	
	1120	20.0	209.14	4.92	
	1122	22.0	209.18	4.96	
	1124	24.0	209.24	5.02	
	1126	26.0	209.30	5.08	
	1128	28.0	209.35	5.13	
	1130	30.0	209.38	5.16	
	1135	35.0	209.45	5.23	
	1140	40.0	209.51	5.29	
	1145	45.0	209.55	5.33	
	1150	50.0	209.60	5.38	
	1155	55.0	209.62	5.40	

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well TAN #1 3ld 6:2 Page 3 of 5

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)		Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11/17/87	1200	60.0		209.62	5.42	
	1210	70.0		209.70	5.48	
	1220	80.0		209.760	5.54	
	1230	90.0		209.84	5.62	
	1245	105.0		209.95	5.73	
	1250	110.0		209.98	5.76	
	1300	120.0		210.00	5.78	
	1315	135.0		210.03	5.81	
	1330	150.0		210.06	5.84	
	1400	180.0		210.09	5.87	
	1415	195.0		210.12	5.90	
	1430	210.0		210.14	5.92	
	1435	~~215.0~~		210.14	Pump Off	Pump Tripped
					Recovery	
	143535	.35	.58	205.8	4.34	
	143555	.55	.93	205.5	4.64	
	143615	1.15	1.25	205.4	4.74	
	143720	2.20	2.33	205.38	4.76	
	143800	3.0	3.0	205.30	4.84	

Breaker was tripped by an increase in T° of pump. We wanted to go until 1500 but once the pump shut down, I immediately started to log the recovery ...

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well TAN #1 Bldg 612

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)		Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
1/17/87	143840	3.40	3.66	205.22	4.92	
	143900	4.0	4.0	205.18	4.96	
	143915	4.15	4.25	205.15	4.99	
	143955	4.55	4.93	205.10	5.04	
	144000	5.0	5.0	205.10	5.04	
	144030	5.30	5.5	205.07	5.07	
	144100	6.0	6.0	205.05	5.09	
	144130	6.50	6.83	205.00	5.14	
	144300	8.0		204.97	5.17	
	144400	9.0		204.91	5.23	
	144500	10.0		204.89	5.25	
	144600	11.0		204.86	5.28	
	144700	12.0		204.84	5.30	
	144900	14.0		204.80	5.34	
	145000	15.0		204.78	5.38	
	145500	20.0		204.70	5.44	
	150000	25.0		204.68	5.46	
	150500	30.0		204.65	5.49	
	151000	40.0		204.62	5.52	

~~TIMED~~ AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well TAN #1 Elev 6'2 Page 5 of 5

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped ~~(minutes)~~	Depth to water, below land surface (feet)	Drawdown or recovery ~~(feet)~~	Remarks
11/17/87	152000	50.0	204.59	5.55	
	153000	60.0	204.57	5.57	
	154500	75.0	204.57	5.57	
	160000	90.0	204.55	5.59	
	162000	110.0	204.54	5.60	
	163500	125.0	204.53	5.61	
		END	TEST		

AQUIFER TEST FIELD DATA SHEET

___ Pumped well Page 1 of 2

✓ Observation well No. TAN #2 (ANP #2)

Owner: DOE Location: TAN Bldg. #613

Observers: R.G. Jensen

Measuring point is Top of 1" line which is ______ feet above/below surface.

Static water level 209.53 feet below land surface.

Distance to pumped well 500.0 feet.

Discharge rate of pumped well 1050 gpm (gallons per minute).

Total number of observation wells 2 + pumped well

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11-17-87	11:00 00	Pump on 0:00	15 min before 213 - 3.42	0	Pump ON
	11:05 00	5:00	Held - Cut 212.00 - 2.35	0.07	
	11:10	10:00	212 - 2.31	0.11	
	11:15	15:00	213 - 3.31	0.11	
	11:25	25:00	213 - 3.32	0.11	
	11:35	35:00	212 - 2.28 = 209.72	0.14	
	11:45	45:00	212 - 2.23 = 209.77	0.19	
	12:00	60:00	212 - 2.23 = 209.77	0.19	
	12:30	90:00	212 - 2.19 = 209.81	0.23	
	12:50	110:00	212 - 2.16 = 209.84	0.26	
	13:00	120:00	212 - 2.15 = 209.85	0.27	
	13:15	135:00	212 - 2.16 = 209.84	0.26	
	13:30	150:00	212 - 2.15 = 209.85	0.27	

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

___ Pumped well Page 2 of 2

✓ Observation well No. ANP#2

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11-17-87	1345	165:00	212.-2.15 = 209.85	0.27	
"	1400	180:00	212-2.15 = 209.85	0.27	
"	1430	210:00	212-2.15 = 209.85	0.27	
"	1445	225:00	212-2.15 = 209.85	0.27	
"	~~Pump~~	~~Tripped~~	~~1445~~	~~Recovery~~	~15 minutes before planned termination
11-17-87	1500	240:00 15 min	212-2.17 = 209.83	0.02	
	1510	250:00 25 min	212-2.22 = 209.78	0.07	
	1520	260:00 35 min	212-2.23 = 209.77	0.08	
	1530	270:00 45 min	212-2.25 = 209.75	0.10	tape sticks to meas. line
	1540	280:00 55 min			cleaned tape
	1550	290:00 65 min	212-2.27 = 209.73	0.12	
	1600	300:00 75 min	212-2.27 = 209.73	0.12	
	1615	315:00 90 min	212.-2.26 = 209.74	0.11	
	1630	330:00 105 min	212-2.27 = 209.73	0.12	
	1645	345:00 120 min	212-2.26 = 209.74	0.11	Terminated test

[redacted]AQUIFER TEST FIELD DATA SHEET

___ Pumped well

X Observation well No. USGS #24

Owner: USGS

Location: 43503112420801
06N 31E 13dbb1
Circular Butte 7.5 quad

Observers: R. Jensen

Measuring point is Top of Well casing which is 1.89 feet above / below surface.

Static water level 209.675 feet below land surface.

Distance to pumped well 1000 feet.

Discharge rate of pumped well 1050 gpm (gallons per minute).

Total number of observation wells 2, USGS 24 and TAN #2 + observation pipe @ TAN #1

Date	Clock time	Elapsed time since pumping started / stopped (~~minutes~~)	Depth to water, below land surface (feet)	Drawdown or recovery (~~feet~~)	Remarks
11/17/87	1100	0	209.675	0	Pump ON
	1115	15	209.70	0.025	
	1130	30	209.75	0.075	
	1200	60	209.80	0.125	
	1230	90	209.825	0.150	
	1300	120	209.850	0.175	
	1330	150	209.875	0.20	
	1400	180	209.90	0.225	
	1435	215	209.915	0.240	
	1435	0	209.915	0	Pump OFF
	1450	15	209.880	0.035	
	1505	30	209.875	0.040	
	1535	60	209.865	0.05	

* Note - Data from water level recorder
A-35 SN 39748-64 AEC PPCo 720-13004

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

___ Pumped well

X Observation well No. USGS #24

Date	Clock time	Elapsed time since pumping started / stopped ~~(minutes)~~	Depth to water, below land surface (feet)	Drawdown or recovery ~~(feet)~~	Remarks
11/17/87	1605	90	209.85	0.065	
	1635	120	209.85	"	
	1705	150	209.85	"	
	1735	180	209.85	"	
	1805	210	209.85	"	

The barometric pressure was rising constantly through both days of the pump test. This can be seen on the water level recorder graph paper.

AQUIFER TEST FIELD DATA SHEET

X Pumped well [redacted] Page 1 of 5

___ Observation well No. ___

Owner: DOE Location: TAN Bldg #613

Observers: LIB

Measuring point is Top of 1" coupler which is 1.67' feet above/below Pump house Floor surface.

Static water level 209.09 feet below land surface.

Distance to pumped well ______ feet. TAN #1 500.0' USGS 24 1000.0'

Discharge rate of pumped well 1010 gpm (gallons per minute).

Total number of observation wells 2 - TAN #1. and USGS 24 plus the pumped well observation pipe

Date	Clock time	Elapsed time since pumping started / stopped (minutes)		Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11/18/87	1015	0		-209.09	0	Pump on
	101530	.30	.50	218.20	9.11	
	101600	1.0	1.0	216.00	6.91	
	101630	1.30	1.50	215.73	6.64	
	101655	1.55	1.93	215.77	6.68	
	101700	2.0	2.0	215.78	6.69	
	101720	2.20	2.33	215.82	6.73	
	101730	2.30	2.50	215.86	6.77	
	101740	2.40	2.62	215.88	6.79	
	101755	2.55	2.93	215.90	6.81	
	101825	3.25	3.42	215.95	6.86	
	101900	4.0	4.0	216.0	6.91	
	102000	5.0	5.0	216.07	6.98	

Time Delay from Pump on - To Pump Running - 75 sec.

~~PROPOSED~~ AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well TAN # 2 Page 2 of 5

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11/18/87		6.0	216.13	7.04	
		7.0	216.17	7.08	
		8.0	216.21	7.12	1000 gpm
		9.0	216.23	7.14	
		10.0	216.25	7.16	
		12.0	216.30	7.21	
		14.0	216.32	7.23	
		16.0	216.36	7.27	
		18.0	216.38	7.29	
	1035	20.0	216.41	7.32	1010 gpm
		22.0	216.43	7.34	
		24.0	216.45	7.36	
		26.0	216.47	7.38	
	1045	30.0	216.50	7.41	
		35.0	216.55	7.46	
		40.0	216.55	7.46	1010 gpm
		45.0	216.58	7.49	
		55.0	216.63	7.54	
	1115	60.0	216.63	7.54	

~~PERCHED~~ AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well TAN #2 Page 3 of 5

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown ~~or~~ recovery (feet)	Remarks
11/18/87		70.0	216.66	7.57	
		80.0	216.66	7.57	
		110.0	216.70	7.61	
	1215	120.0	216.70	7.61	
		130.0	216.72	7.63	
		140.0	216.72	7.63	
	1245	150.0	216.73	7.64	
		160.0	216.73	7.64	
		170.0	216.73	7.64	
	1315	180.0	216.74	7.65	
		190.0	216.75	7.66	
		200.0	216.74	7.65	
	1345	210.0	216.75	7.66	
		220.0	216.76	7.67	
	1405	230.0	216.76	7.67	
	1415	240.0	216.76	7.67	
		0	216.76	[illegible]	Pump OFF
		Recovery - Next page			

~~[illegible]~~ AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well Tan #2 Page 4 of 5

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery ~~(feet)~~	Remarks
11/18/87		.35 / .58	208.47	8.29	
		.50 / .83	207.95	8.81	
		1.15 / 1.25	208.25	8.51	
		1.35 / 1.58	208.85	7.91	
		1.50 / 1.83	207.00	7.76	
		2.35 / 2.58	209.75	7.01	
		3.10 / 3.16	209.70	7.06	
	1419	4.0	209.71	7.05	
		6.0	209.60	7.16	
		7.0	209.56	7.20	
		8.0	209.54	7.22	
		9.0	209.52	7.24	
	1425	10.0	209.50	7.26	
		12.0	209.47	7.29	
		14.0	209.44	7.32	
		16.0	209.42	7.34	
		18.0	209.40	7.36	
	1435	20.0	209.38	7.38	
		25.0	209.34	~~7.34~~ 7.42	

PERCHED AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well Tar #2 Page 5 of 5

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11/18/87	1445	30.0	209.33	7.43	
		35.0	209.31	7.45	
		40.0	209.29	7.47	
	1505	50.0	209.25	7.51	
		70.0	209.20	7.56	
	1535	80.0	209.19	7.56	
	1540	85.0	209.19	7.56	
		END	TEST		
		Iron Horse "0.0"	top of		
		1" coupler			

AQUIFER TEST FIELD DATA SHEET

___ Pumped well

X Observation well No. USGS #24

Owner: USGS

Location: 06N 31E 13dbb1
Circular Butte 7.5 quad

Observers: LB

Measuring point is Top of casing which is 1.09 feet above/below surface.

Static water level 210.02 feet below land surface.

Distance to pumped well 1000 feet. TAN #2

Discharge rate of pumped well 1010 gpm (gallons per minute).

Total number of observation wells 2, Tan #1, USGS #24, and observation pipe @ Pumped well

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11/18/87	1015	0	210.02	0	Pump on
	1030	15	210.05	0.03	
	1045	30	210.055	0.035	
	1100	45	210.070	0.05	
	1130	75	210.085	0.065	
	1200	105	210.10	0.08	
	1230	135	210.11	0.09	
	1300	165	210.125	0.105	
	1330	195	210.13	0.11	
	1400	225	210.14	0.12	
	1415	240	210.15	0.13	
	1415	0	210.15	0	Pump OFF
	1430	15	210.145	0.005	

PERCHED AQUIFER TEST FIELD DATA SHEET
Continuation sheet

___ Pumped well

Page 2 of 2

X Observation well No. USGS 24

Date	Clock time	Elapsed time since pumping started / stopped ([redacted]s)	Depth to water, below land surface (feet)	Drawdown or recovery ~~(feet)~~	Remarks
11/18/87	1500	45	210.14	0.01	
	1530	75	210.11	0.04	
	1600	105	210.09	0.06	
	After	1600	hrs, water -	level	
	started	to drop	again -	due	
	to	Barometric	Pressure,	or	so
	it	looks on	recorder	chart	

~~PERCHED~~ AQUIFER TEST FIELD DATA SHEET

___ Pumped well

✓ Observation well No. TAN #1

Owner: DOE Location: TAN Bldg. 612

Observers: R. Jensen

Measuring point is 1" Coupling which is 1.45 feet above/below Pump house floor surface.

Static water level 206.60 feet below land surface.

Distance to pumped well 500' feet.

Discharge rate of pumped well 1010 gpm (gallons per minute).

Total number of observation wells 2 + pumped well

Date 1987	Clock time	Elapsed time since pumping ~~started~~ / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11-18	1015	0:00	-206.40	0.00	pump on
	1017	2:00	206.43	0.03	
	1020	5:00	.45	0.05	
	1025	10:00	.47	0.07	
	1030	15:00	.48	0.08	
	1035	20:00	.49	0.09	
	1045	30:00	.51	0.11	
	1055	40:00	.52	0.12	
	1110	55:00	.55	0.15	
	1125	70:00	.56	0.16	
	1135	80:00	.56	0.16	
	1205	110:00	.58	0.18	
	1225	130:00	.59	0.19	

~~Recovery~~ AQUIFER TEST FIELD DATA SHEET
Continuation sheet

___ Pumped well

Page 2 of 3

✓ Observation well No. TAN#1

Date 1987	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11-18	1245	150:00	206.59	0.19	
	1305	170:00	.60	0.20	
	1325	190:00	.61	0.21	
	1345	210:00	.61	0.21	
	1400	225:00	.62	0.22	
	1415	240:00	63	—	
	1417	242:00		Recovery	pump off
	18	1:00	206.62	0.01	
	19	2:00	.60	0.02	
	20	3:00	.59	0.03	
	21	4:00	.58	0.04	
	22	5:00	.58	0.04	
	24	7:00	.57	0.05	
	26	9:00	.56	0.06	
	28	11:00	.55	0.07	
	1430	13:00	.55	0.07	
	1435	18:00	.54	0.08	
	1440	23:00	.53	0.09	
	1445	28:00	.52	0.10	

PERCHED AQUIFER TEST FIELD DATA SHEET
Continuation sheet

___ Pumped well

✓ Observation well No. TAN #1

Date 1987	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
11-18	1448	31:00	206.51	0.11	
	1453	36:00	.50	0.12	
	1458	41:00	.50	0.12	
	1508	51:00	.48	0.14	
	1518	61:00	.47	0.15	
	1528	71:00	.46	- 0.16	
	1537	80:00	.45	0.17	
	1547	90:00	.45	0.17	

USGS CALCULATIONS

Pump Test IET°1 7/9/87

Well Depth 324.0 feet

Present Water level 207.42 feet below surface

Saturated thickness 116.58' feet

K + T - by Theis curve

$T = 78.18\ ft^2/d$

$K = 0.67\ ft/d$

K & T by Sw over one log cycle of time

$T = 596.3\ ft^2/d$

$K = 5.1\ ft/d$

$S_c = \dfrac{19.99\ gal/min}{2.64\ S_w} = 7.57\ gpm/foot\ S_w$

Pump Test IS 1 7/9/87

$TD = 324$ ft

$B' = 116$ ft

$T = 78$ ft^2/day

$K = 0.7$ ft/day

$Q = 90$ gal/min

$S_w = 2.35$ ft

$S_c = 8.5$ gpm/ft

AQUIFER TEST FIELD DATA SHEET

X Pumped well IET #1 Page 1 of 4

___ Observation well No. ___

Owner: Location: CIRCULAR Butte 7.5'
06N 31E 12acd1

Observers: L. Beem, R Jensen

Measuring point is Top of 1" coupler which is ______ feet above/below surface.

Static water level 207.42 feet below land surface. Iron Horse
Well depth 324.0'

Distance to pumped well ——— feet.

Discharge rate of pumped well 19.99 gpm (gallons per minute).

Total number of observation wells ———.

FM START 84068
STOP: 86467 2399 gal / 120 min = 19.99 gpm

Attempt to adjust FM to ~~[illegible]~~ 20.

Date	Clock time	Elapsed time since pumping started / stopped ~~(minutes)~~		Depth to water, below land surface (feet)	Drawdown or recovery ~~(feet)~~	Remarks
7/9/87	121500	0		207.42	0	Pump ON
	121515	15	.25	207.45	0.03	
	121530	30	.50	207.80	0.38	
	121545	45	.75	208.00	0.58	
	121600	1.0	1.00	208.10	0.68	
	121620	1.20	1.33	208.43	1.01	
	121630	1:30	1.50	208.65	1.23	
	121656	1:56	1.93	208.69	1.27	
	121715	2:15	2.25	208.76	1.34	
	121732	2:32	2.53	208.80	1.38	
	121750	2:50	2.83	208.85	1.43	
	121824	3:24	3.40	208.91	1.49	
	121845	3:45	3.75	208.95	1.53	

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well IET#1 Page 2 of 4

___ Observation well No. —

Date	Clock time	Elapsed time since pumping ~~started~~/stopped ~~(minutes)~~		Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
7/9/87	121935	4:35	4.58	209.00	1.58	
	122010	5:10	5.16	209.04	1.62	
	122145	6:45	6.75	209.03	1.61	10gal/37sec
	122400	9.0	9.0	209.03	1.61	Increased Q
	122600	11.0	11.0	209.02	1.60	"
	122730	12.30	12.50	209.11	1.69	Increased Q
	122900	14.0	14.0	209.26	1.84	Increased Q
	123000	15.0	15.0	209.57	2.15	10gal/29.5sec
	123115	16.15	16.25	209.59	2.17	≈20gpm
	123325	18.25	18.42	209.65	2.23	
	123500	20.0		209.67	2.25	
	123600	21.0		209.68	2.26	
	123700	22.0		209.69	2.27	
	123800	23.0		209.69	2.27	≈20gpm
	124000	25.0		209.69	2.27	
	124500	30.0		209.70	2.28	
	125500	40.0		209.72	2.30	
	131500	60.0		209.73	2.31	
	133000	75.0		209.74	2.32	

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well

___ Observation well No. ___

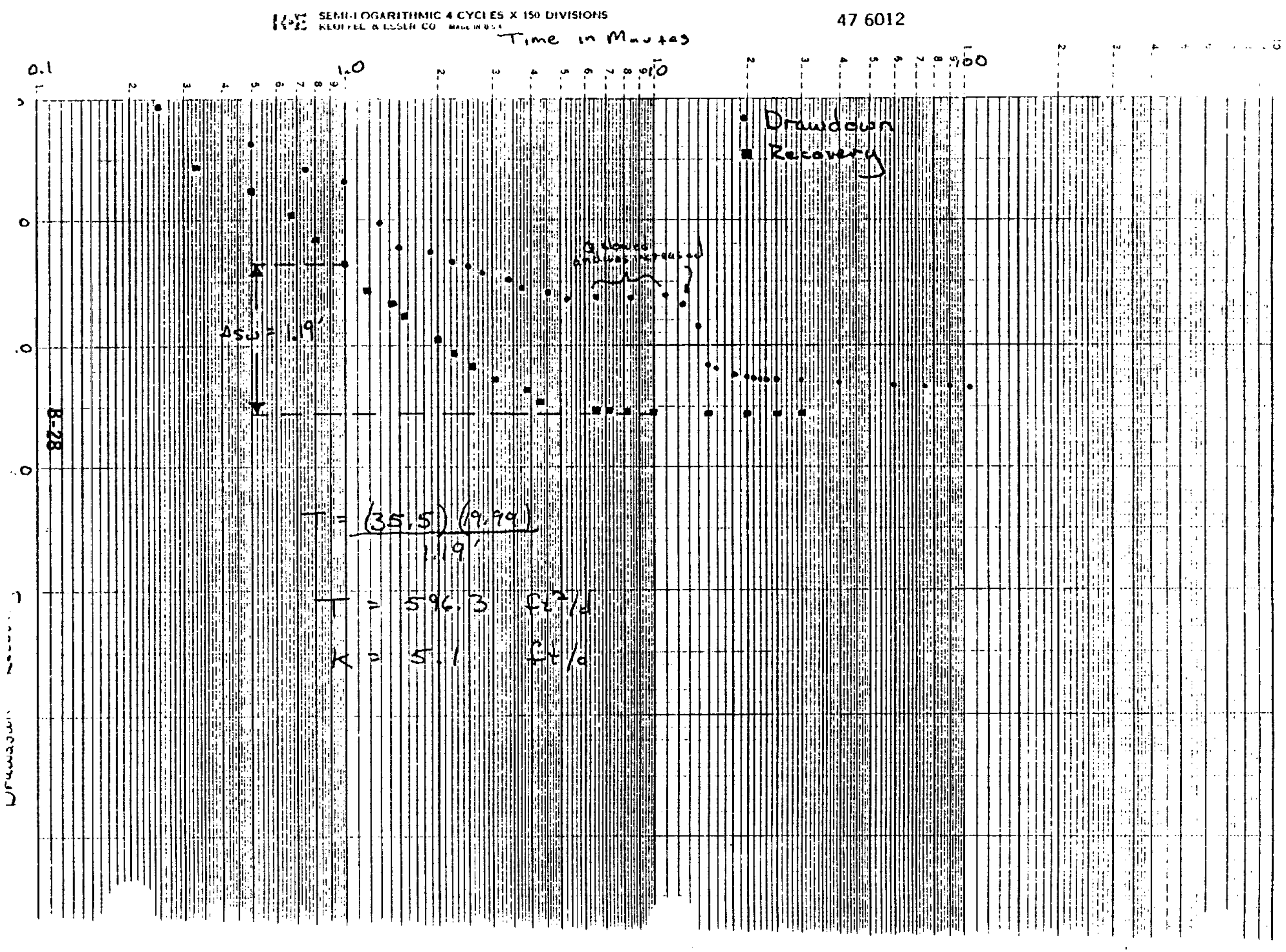
Date	Clock time	Elapsed time since pumping started / stopped (minutes)		Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
7/9/87	134500	90.0		209.75	2.33	
	140000	105.0		209.76	2.34	
	~~141000~~	~~120.0~~		~~209.77~~	~~2.35~~	~~2:07pm~~
	141500	-0-		209.77	-0-	Pump OFF
	141520	.20	.33	209.20	0.57	
	141530	:30	.50	209.00	0.77	
	141540	:40	.67	208.80	0.97	
	141548	:48	.80	208.60	1.17	
	141601	1:01	1.0	208.40	1.37	
	141617	1:17	1.28	208.20	1.57	
	141625	1:25	1.42	208.10	1.67	
	141634	1:34	1.56	208.00	1.77	
	141700	2:00	2.0	207.80	1.97	
	141716	2:16	2.26	207.70	2.07	
	141735	2:35	2.58	207.60	2.17	
	141803	3:03	3.05	207.50	2.27	
	141854	3:54	3.90	207.40	2.37	
	141917	4:17	4.28	207.35	2.42	
	142025	5:25	5.42	207.30	2.47	

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

___ Pumped well IET Dip

___ Observation well No. ___

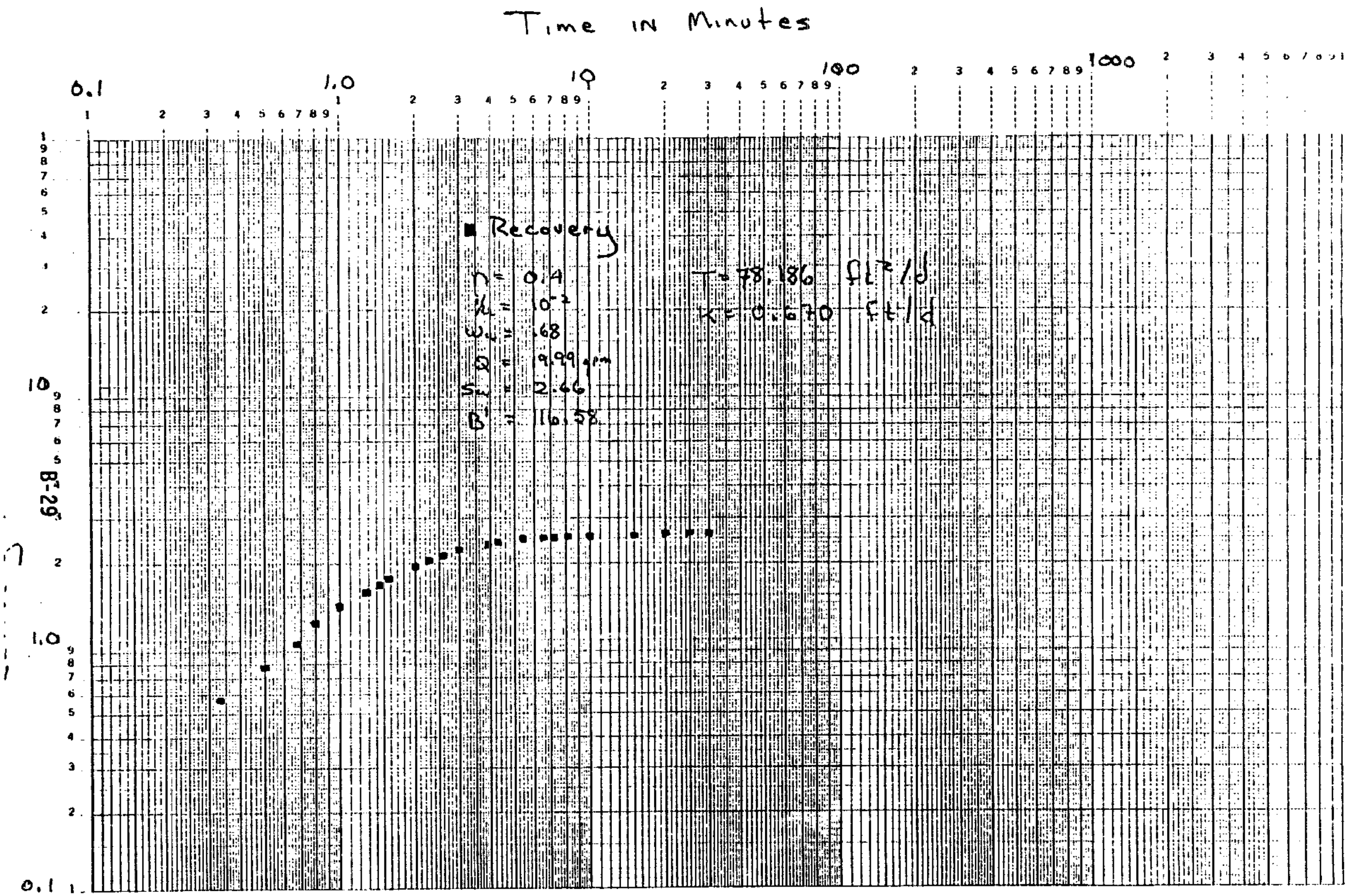
Date	Clock time	Elapsed time since pumping started / stopped ~~(minutes)~~		Depth to water, below land surface (feet)	Drawdown or recovery ~~(feet)~~	Remarks
7/9/87	142130	6:30	6.50	207.26	2.51	
	142213	7:13	7.22	207.24	2.53	
	142310	8:10	8.16	207.23	2.54	
	142500	10:00	10.0	207.21	2.56	
	143000	15.0	15.0	~~207.27~~ 207.17	2.6	
	144500	20.0	20.0	~~207.26~~ 207.16	2.61	
	144000	25.0	25.0	~~207.24~~ 207.14	2.63	
	144500	30.0	30.0	~~207.23~~ 207.13	2.64	
		END TEST				
		Counter		0.0 top	of	
		1"		coupler.		



K+E SEMI-LOGARITHMIC 4 CYCLES X 150 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
47 6012
Time in Minutes
0.1
1.0
10
100
Drawdown
Recovery
$\Delta s = 1.9'$
$T = \frac{(35.5)(9.99)}{1.19'}$
$T = 596.3 \ ft^2/d$
$K = 5.1 \ ft/d$
B-28

K•E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522



USGS CALCULATIONS

Pump Test TAN DISP (ANP = 3) 7/13/87

Well Depth - 310.00 feet

Present Water level - 195.78 feet below surface

Saturated thickness - (B') - 114.22 feet

<u>T and K</u> by Sw over one log cycle:

$T = 97.34\ ft^2/d$

$K = 0.85\ ft/d$

<u>T and K</u> by Theis curve method (Recovery)

$T = 60.16\ ft^2/d$

$K = 0.526\ ft/d$

$n = 0.03$
$1/u = 10^{-2}$
$W_u = 2.42$
$S_w = 12.1$
$Q = 19.66$
$B' = 114.22$

Pump Test (ANP#2' AN DISP. 7/13/87

TD = 310 ft

B' = 114 ft

T = 60 ft^2/day

K = 0.5 ~~0~~ ft/day

Q = 19.7 gpm

Sw = 12.68 ft

Sc = 1.6 gpm/ft

AQUIFER TEST FIELD DATA SHEET

X Pumped well TAM Disp. ⇒ ANP 3 Page 1 of 4

___ Observation well No. ___

Owner: Location: Circular Butte, 7.5'
06N 31E 13cabl

Observers: L. Beem, R Jensen

Measuring point is Top of 1" coupler which is 1.45 feet above/below surface.

Static water level 195.78 feet below land surface. From Horse Well Depth 310

Distance to pumped well ——— feet.

Discharge rate of pumped well 19.66 gpm (gallons per minute).

Total number of observation wells ——.

FM START 93731
STOP 95206 1475 gal / 75 min

Date	Clock time	Elapsed time since pumping started / stopped ~~(minutes)~~		Depth to water, below land surface (feet)	Drawdown or recovery ~~(feet)~~	Remarks
7/13/87	095500	-0-		195.78	-0-	Pump on
	095515	.15	.25	196.0	0.22	10 gal 30 sec
	095550	.50	.83	196.95	1.17	
	095610	1.10	1.16	197.18	1.40	
	095625	1.25	1.42	197.30	1.52	
	095700	2.00	2.0	197.50	1.72	
	095725	2.25	2.42	197.85	2.07	
	095810	3.10	3.16	198.45	2.67	
	095835	3.35	3.58	199.10	3.32	
	095845	3.45	3.75	199.40	3.62	
	095920	4.20	4.33	200.00	4.22	20 gal min
	095944	4.44	4.73	200.40	4.62	
	100025	5.20	5.33	201.00	5.22	

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well Tan Disp -AN#3)

Page 2 of 4

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
7/13/87	100010	6.10 6.16	201.80	6.02	
	100130	6.30 6.50	202.00	6.22	
	100150	6.50 6.83	202.30	6.52	
	100215	7.15 7.25	202.60	6.82	
	100250	7.50 7.83	203.00	7.22	
	100335	8.35 8.58	203.50	7.72	
	100435	9.35 9.58	204.00	8.22	
	100540	10.40 10.66	204.50	8.72	
	100700	12.00 12.00	205.05	9.27	10gal/ 30.5 sec
	100820	13.20 13.33	205.55	9.77	
	101000	15.00 15.0	206.03	10.25	
	101500	20.00 20.0	207.10	11.32	
	102000	25.00 25.0	207.58	11.80	
	102500	30.00 30.0	207.92	12.14	
	103000	35.00 35.0	208.17	12.39	
	103600	41.00	208.39	12.61	
	104000	45.00	208.53	12.75	
	105000	55.00	208.73	12.95	10ga / 31 sec
	105500	60.00	208.53	12.75	

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well TAN DISP. ANP #3

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)		Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
7/13/87	105800	63		208.46	12.68	10 gal/32 sec
	110000	65		208.43	12.65	
	110500	70		208.43	12.65	
	~~111000~~	~~75~~		~~208.46~~	~~12.68~~	~~5 gal/52 sec~~
	111000	~~0~~		208.46	~~0~~	Pump OFF
	111010	.10	.16	207.00	0.46	
	111035	35	.52	207.20	1.26	
	111050	.50	.83	206.60	1.86	
	111100	1.0	1.0	206.00	2.46	
	111123	1.23	1.38	205.40	3.06	
	111135	1.35	1.58	205.00	3.46	
	111210	2.10	2.16	204.00	4.46	
	111225	2.25	2.42	203.60	4.86	
	111245	245	2.75	203.20	5.26	
	111255	2.55	2.93	203.00	5.46	
	111320	3.20	3.33	202.50	5.96	
	111400	4.0	4.0	201.80	6.66	
	111500	5.0	5.0	201.00	7.46	
	111625	6.25	6.42	200.00	8.46	

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

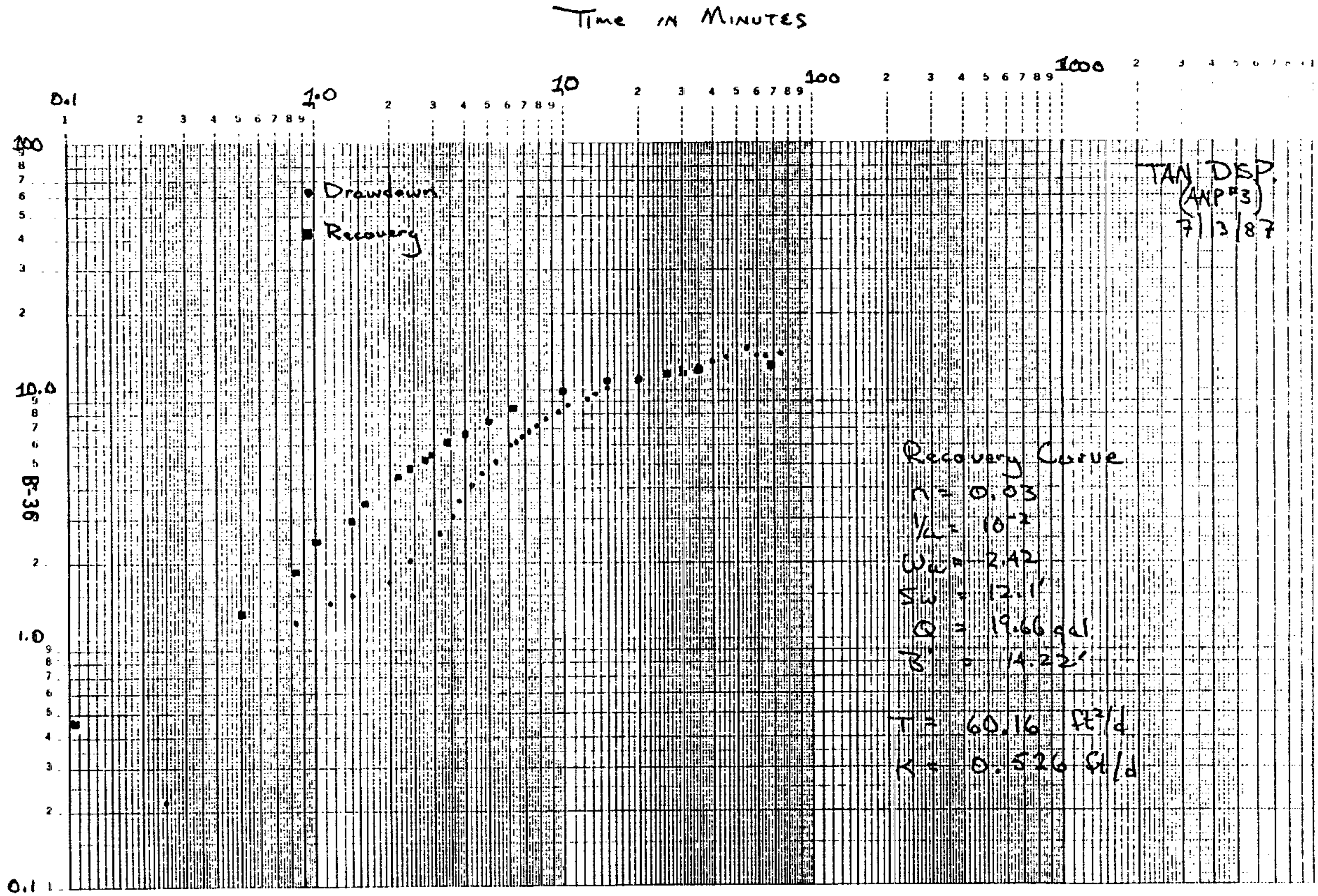
✓ Pumped well TAN DISP. (AMP=2)　　　　Page 4 of 4

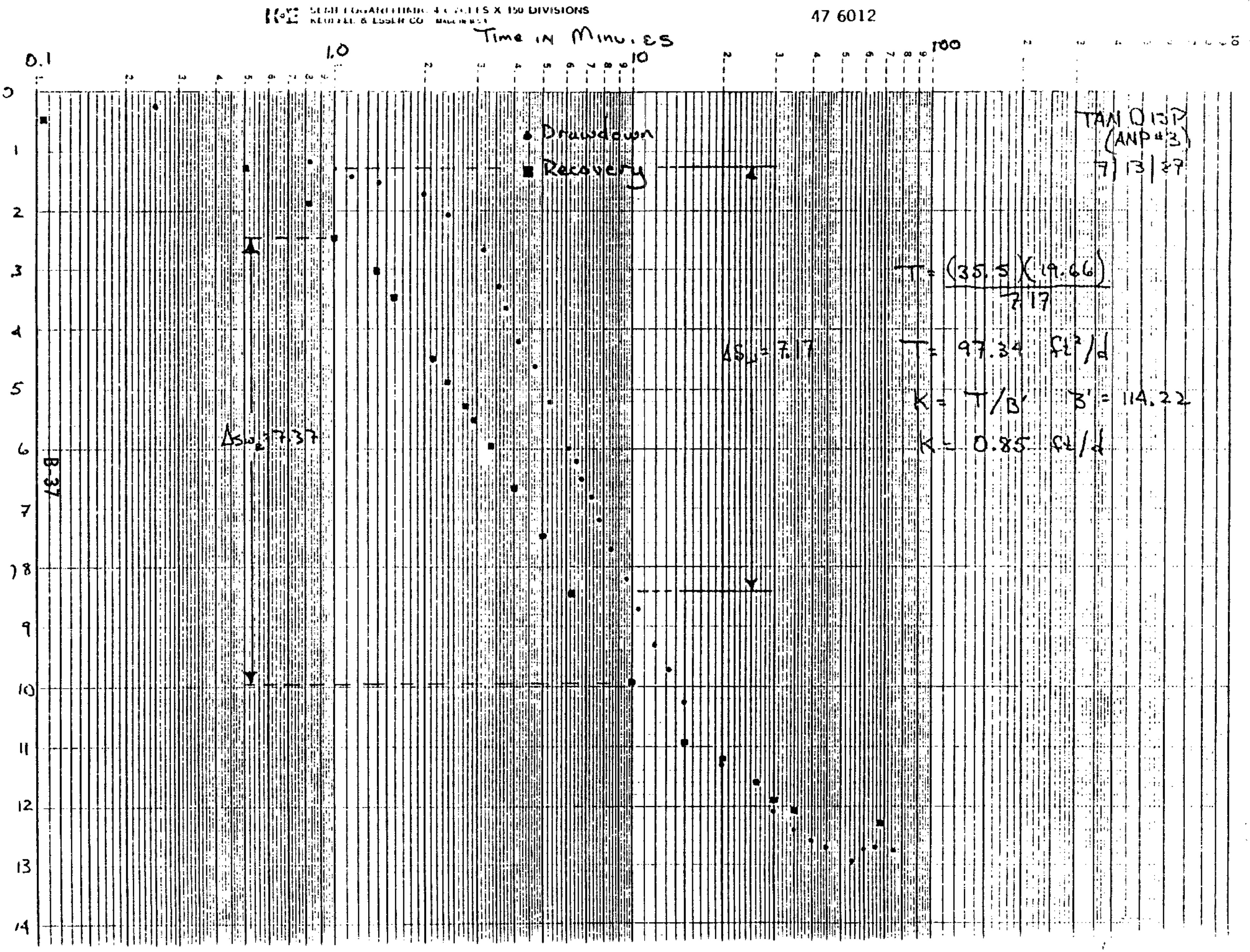
___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
7/13/87	112000	10.0	198.50	9.96	
	112500	15.0	197.50	10.96	
	113000	20.0	197.26	11.20	
	113600	26.0	196.83	11.63	
	114000	30.0	196.58	11.88	
	114500	35.0	196.42	12.04	
	121800	68.0	195.98	12.48	0.20 short of SWL prior to pumping
		END TEST			
		Counter 0.0 top of			
		1" coupler			

K&E LOGARITHMIC 3 x 5 CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 7522





K&E SEMI-LOGARITHMIC 4 CYCLES X 150 DIVISIONS
KEUFFEL & ESSER CO.
47 6012
Time in Minutes
• Drawdown
■ Recovery
TAN O137
(ANP #3)
7/13/87
$\Delta s_w = 7.37$
$\Delta s_w = 7.17$
$T = \frac{(35.5)(19.66)}{7.17}$
$T = 97.34\ ft^2/d$
$K = T/B'$ $B' = 114.22$
$K = 0.85\ ft/d$
B-37

Pump Test ANP #6 7/10/87

Well Depth - 305.25

Present Water level - 206.24.

Saturated thickness - 99.01

No drawdown noted.

Pump TEST ANF - 6 0187

$S_w = 0.00$ ft

$Q = 40.3$ gal/min

$B' = 99$ ft

AQUIFER TEST FIELD DATA SHEET

X Pumped well ANP # 6

___ Observation well No. ___

Owner: USGS

Location: Circular Butte 7.5'
06N 31E 10 accl

Observers: L. Beem

Measuring point is Top of 1" coupler which is ______ feet above/below surface.

Static water level 206.24 feet below land surface. Iron Horse
Total Depth 305.25

Distance to pumped well ——— feet.

Discharge rate of pumped well 40.27 gpm (gallons per minute).

Total number of observation wells ———.

F.M 86481 START
93731 Stop 7250 gal / 180 min = 40.27

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
7/10/87	100000	~~0~~	206.24	~~0~~	Pump on
|	100020	.20	206.24	0.0	
|	100040	40	206.24	0.0	
|	100100	1.0	206.24	0.0	
|	100200	2.0	206.24	0.0	
|	100300	3.0	206.24	0.0	
|	100500	5.0	206.24	0.0	
|	101000	10.0	206.24	0.0	
|	102000	20.0	206.24	0.0	
|	104500	45.0	206.24	0.0	
|	110000	60.0	206.24	0.0	
/	113000	90.0	206.24	0.0	
/	121500	135.0	206.24	0.0	

AQUIFER TEST FIELD DATA SHEET
Continuation sheet

X Pumped well ANP # 6

___ Observation well No. ___

Date	Clock time	Elapsed time since pumping started / stopped (minutes)	Depth to water, below land surface (feet)	Drawdown or recovery (feet)	Remarks
7/10/87	130000	180	206.24	0.0	
7/10/87	13000	~~0~~	206.24	~~0~~	Pump OFF
		END TEST			
		No drawdown recorded			
		Counter 0.0 top of 1" coupler			

APPENDIX C

LOGAN'S METHOD FOR STEADY-STATE FLOW

The pumping test conducted in ANP-6 utilized a discharge rate of 40.27 gpm over 180 min. This was insufficient to cause any measurable drawdown. To calculate an approximate transmissivity, conventional solutions could not be used because no drawdown occurred in the borehole. A steady-state approximation method was used but provides only a minimum value for transmissivity. A minimum transmissivity of 3114 ft^2/day (88.2 m^2/d) was calculated.

Logan's method for a steady-state flow in confined aquifers (Kruseman and De Rigger, 1976) represents an approximation of the Theim formula for a confined aquifer and was used for the calculation of transmissivity. The groundwater in the aquifer is assumed to be confined. The constant rate of pumpage and the absence of drawdown justify a steady-state condition.

$$kD = \frac{2.30Q \log r_{max}/r_w}{2\pi s_{mw}}$$

where:

kD = transmissivity of the aquifer, m^2/d

Q = well discharge, m^3/d

r_w = radius of the pumped well, m

r_{max} = radius of influence (= radius of depression cone, m)

s_{mw} = maximum drawdown in the pumped well, m.

The ratio of r_{max}/r_w cannot be accurately determined without the use of additional piezometers. However, although the variations in r_{max} and r_w may be substantial, the variation in the logarithm of their ratio is much smaller and can be approximated with an average value of 3.33. Substituting this value into the above equation yields:

$$kD = \frac{1.20\ Q}{s_{mw}}$$

As was mentioned earlier, no drawdown was observed in the well, but a drawdown is needed to calculate transmissivity with this equation. A drawdown of 0.1 meters was used. Using the same discharge as in the pumping test (40.27 gpm [7.35 m^3/d]) with this drawdown yields a minimum value of 3114 ft^2/day (88.2 m^2/d). Transmissivity must be higher because there was not drawdown. Based on a saturated thickness of 99.01 feet, the minimum K for well ANP-6 is 31.5 ft/day. These calculated values are minimums and the actual T and k could be much higher than the values presented here.

Appendix K

Number

APPENDIX K

ORGANIC AND INORGANIC ANALYTICAL RESULTS--
TSF CLARIFIER PITS

RESULTS OF ORGANIC ANALYSES OF
THE TSF CLARIFIER PITS

NOTES FOR ORGANICS RESULTS

U -- indicates compound was analyzed for but not detected.

J -- indicates an estimated value. This flag is used when estimating the concentration of tentatively identified compounds or when compound is identified but the concentration is less than the sample quantitation limit.

B -- analyte found in the associated blank as well as in the sample.

D -- identifies all compounds identified in an analysis at a secondary dilution factor.

NOTES FOR INORGANICS RESULTS

U -- indicates compound was analyzed for but not detected.

B -- indicates the reported value is less than the Contract Required Detection Limit (CRDL) but greater than the Instrument Detection Limit (IDL).

E -- indicates a value estimated or not reported due to the presence of interference.

S -- indicates value determined by Method of Standard Addition.

N -- indicates matrix spike sample recovery is not within control limits.

* -- indicates duplicate analysis is not within control limits.

+ -- indicates that the correlation coefficient for Method of Standard Addition is less than 0.995.

VOLATILE ORGANICS
TSF CLARIFIER PIT 1

Analyte	Qual-ifier	Mean Conc. (ppb)	Range	Count
1,1,1-TRICHLOROETHANE		6.5	3	2
1,1,2,2-TETRACHLOROETHANE	U	5.0	0	2
1,1,2-TRICHLOROETHANE	U	5.0	0	2
1,1-DICHLOROETHANE	U	5.0	0	2
1,1-DICHLOROETHENE	U	5.0	0	2
1,1-DICHLOROETHENE (TOTAL)		6.0	0	1
1,1-DICHLOROETHENE (TOTAL)	U	5.0	0	1
1,2-DICHLOROETHANE	U	5.0	0	2
1,2-DICHLOROPROPANE	U	5.0	0	2
2-BUTANONE	U	10.0	0	2
2-HEXANONE	U	10.0	0	2
4-METHYL-2-PENTANONE	U	10.0	0	2
ACETONE	J	2.0	0	1
ACETONE	U	10.0	0	1
BENZENE	U	5.0	0	2
BROMODICHLOROMETHANE	U	5.0	0	2
BROMOFORM	U	5.0	0	2
BROMOMETHANE	U	10.0	0	2
CARBON DISULFIDE	U	5.0	0	2
CARBON TETRACHLORIDE	U	5.0	0	2
CHLOROBENZENE	U	5.0	0	2
CHLOROETHANE	U	10.0	0	2
CHLOROFORM	U	5.0	0	2
CHLOROMETHANE	U	10.0	0	2
CIS-1,3-DICHLOROPROPENE	U	5.0	0	2
DIBROMOCHLOROMETHANE	U	5.0	0	2
ETHYLBENZENE	J	3.5	1	2
METHYLENE CHLORIDE		93.0	14	2
STYRENE	U	5.0	0	2
TETRACHLOROETHENE	U	5.0	0	2
TOLUENE		15.0	8	2
TRANS-1,3-DICHLOROPROPENE	U	5.0	0	2
TRICHLOROETHENE	U	5.0	0	2
VINYL ACETATE	U	10.0	0	2
VINYL CHLORIDE	U	10.0	0	2
XYLENE (TOTAL)		42.0	10	2

SEMIVOLATILE ORGANICS
TSF CLARIFIER PIT 1

Analyte	Qual-ifier	Mean Conc. (ppb)	Range	Count
1,2,4-TRICHLOROBENZENE	U	75.0	10	2
1,2-DICHLOROBENZENE	U	75.0	10	2
1,3-DICHLOROBENZENE	U	75.0	10	2
1,4-DICHLOROBENZENE	U	75.0	10	2
2,4,5-TRICHLOROPHENOL	U	400.0	0	2
2,4,6-TRICHLOROPHENOL	U	75.0	10	2
2,4-DICHLOROPHENOL	U	75.0	10	2
2,4-DIMETHYLPHENOL	U	75.0	10	2
2,4-DINITROPHENOL	U	400.0	0	2
2,4-DINITROTOLUENE	U	75.0	10	2
2,6-DINITROTOLUENE	U	75.0	10	2
2-CHLORONAPHTHALENE	U	75.0	10	2
2-CHLOROPHENOL	U	75.0	10	2
2-METHYLNAPHTHALENE	J	11.5	1	2
2-METHYLPHENOL	U	75.0	10	2
2-NITROANILINE	U	400.0	0	2
2-NITROPHENOL	U	75.0	10	2
3,3-DICHLOROBENZIDINE	U	150.0	100	2
3-NITROANILINE	U	400.0	0	2
4,6-DINITRO-2-METHYLPHENOL	U	400.0	0	2
4-BROMOPHENYL-PHENYLETHER	U	75.0	10	2
4-CHLORO-3-METHYLPHENOL	U	75.0	10	2
4-CHLOROANILINE	U	75.0	10	2
4-CHLOROPHENYL-PHENYLETHER	U	75.0	10	2
4-METHYLPHENOL	U	75.0	10	2
4-NITROANILINE	U	400.0	0	2
4-NITROPHENOL	U	400.0	0	2
ACENAPHTHENE	U	75.0	10	2
ACENAPHTHYLENE	U	75.0	10	2
ANTHRACENE	U	75.0	10	2
BENZO(A)ANTHRACENE	U	75.0	10	2
BENZO(A)PYRENE	U	75.0	10	2
BENZO(B)FLUORANTHENE	U	75.0	10	2
BENZO(G,H,I)PERYLENE	U	75.0	10	2
BENZO(K)FLUORANTHENE	U	75.0	10	2
BENZOIC ACID	U	400.0	0	2
BENZYL ALCOHOL	U	75.0	10	2
BIS(2-CHLOROETHOXY)METHANE	U	75.0	10	2
BIS(2-CHLOROETHYL)ETHER	U	75.0	10	2
BIS(2-CHLOROISOPROPLY)ETHER	U	75.0	10	2
BIS(2-ETHYLHEXYL)PHTHALATE		170.0	40	2
BUTYLBENZYLPHTHALATE		111.0	58	2
CHRYSENE	U	75.0	10	2
DI-N-BUTYLPHTALATE		210.0	100	2
DI-N-OCTYLPHTHALATE	J	11.0	4	2
DIBENZ(A,H)ANTHRACENE	U	75.0	10	2
DIBENZOFURAN	U	75.0	10	2

SEMIVOLATILE ORGANICS
TSF CLARIFIER PIT 1

Analyte	Qual-ifier	Mean Conc. (ppb)	Range	Count
DIETHYLPHTHALATE	U	75.0	10	2
DIMETHYLPHTHALATE	U	75.0	10	2
FLUORANTHENE	U	75.0	10	2
FLUORENE	U	75.0	10	2
HEXACHLOROBENZENE	U	75.0	10	2
HEXACHLOROBUTADIENE	U	75.0	10	2
HEXACHLOROCYCLOPENTADIENE	U	75.0	10	2
HEXACHLOROETHANE	U	75.0	10	2
INDENO(1,2,3-CD)PYRENE	U	75.0	10	2
ISOPHORONE	U	75.0	10	2
N-NITROSO-DI-N-PROPYLAMINE	U	75.0	10	2
N-NITROSODIPHENYLAMINE (1)	J	21.0	6	2
NAPHTHALENE	J	15.0	2	2
NITROBENZENE	U	75.0	10	2
PENTACHLOROPHENOL	U	400.0	0	2
PHENANTHRENE	U	75.0	10	2
PHENOL	U	75.0	10	2
PYRENE	U	75.0	10	2

TIC VOLATILES
TSF CLARIFIER PIT 1

Analyte	Qual-ifier	Mean Conc. (ppb)	Minimum	Maximum	Range	Count
CYCLIC COMPOUND	J	28	15	41	26	2
UNKNOWN	J	33	33	33	0	1
UNSATURATED HYDROCARBON	J	28	14	42	28	2

TIC SEMIVOLATILES
TSF CLARIFIER PIT 1

Analyte	Qual-ifier	Mean Conc. (ppb)	Minimum	Maximum	Range	Count
4-(1,3,3-TETRAMETHYLBUTYL)-PH	J	160000	160000	160000	0	1
ALKYL SUBSTITUTED CYCLOPENTAN	J	96000	96000	96000	0	1
BUTANE,2,2,3,3-TETRAMETHYL	J	97000	97000	97000	0	1
CYCLOHEXANE,1-METHYL-3-PROPYL	J	170000	170000	170000	0	1
DECANE,2-METHYL	J	230000	230000	230000	0	1
DECANE-2,3,7-TRIMETHYL	J	110000	110000	110000	0	1
NONANE,2-METHYL	J	600000	600000	600000	0	1
OCTANE,2-METHYL-	J	610000	610000	610000	0	1
PHENOL,4-(2,2,3,3-TETRAMETHYL	J	130000	130000	130000	0	1
PHENOL,4-CHLORO-2(PHENYLMETHY	J	220000	220000	220000	0	1
UNDECANE,3,8-DIMETHYL	J	150000	150000	150000	0	1
UNDECANE,4,7-DIMETHYL	J	230000	230000	230000	0	1
UNK SUBST HYDROCARBON	J	110000	110000	110000	0	1
UNKNOWN	J	182000	92000	340000	248000	10
UNKNOWN CYCLOALKANE	J	115000	110000	120000	10000	2
UNKNOWN HYDROCARBON	J	311400	96000	840000	744000	15

PESTICIDE ORGANICS
TSF CLARIFIER PIT 1

Analyte	Qual-ifier	Mean Conc. (ppb)	Range	Count
4,4-DDD	U	1700	0	2
4,4-DDE	U	1700	0	2
4,4-DDT	U	1700	0	2
ALDRIN	U	840	0	2
ALPHA CHLORDANE	U	8400	0	2
ALPHA-BHC	U	840	0	2
AROCLOR 1016	U	8400	0	2
AROCLOR 1221	U	8400	0	2
AROCLOR 1232	U	8400	0	2
AROCLOR 1242	U	8400	0	2
AROCLOR 1248	U	8400	0	2
AROCLOR 1254	U	17000	0	2
AROCLOR 1260	J	10000	0	1
AROCLOR 1260	U	14000	0	1
BETHA-BHC	U	840	0	2
DELTA-BHC	U	840	0	2
DIELDRIN	U	1700	0	2
ENDOSULFAN I	U	840	0	2
ENDOSULFAN II	U	1700	0	2
ENDOSULFAN SULFATE	U	1700	0	2
ENDRIN	U	1700	0	2
ENDRIN KETONE	U	1700	0	2
GAMMA CHLORDANE	U	8400	0	2
GAMMA-BHC	U	840	0	2
HEPTACHLOR	U	840	0	2
HEPTRACHLOR EPOXIDE	U	840	0	2
METHOXYCHLOR	U	8400	0	2
TOXAPHENE	U	17000	0	2

VOLATILE ORGANICS
TSF CLARIFIER PIT 3

Analyte	Qual-ifier	Mean Conc. (ppb)	Range	Count
1,1,1-TRICHLOROETHANE	U	5.0	0	2
1,1,2,2-TETRACHLOROETHANE	U	5.0	0	2
1,1,2-TRICHLOROETHANE	U	5.0	0	2
1,1-DICHLOROETHANE	U	5.0	0	2
1,1-DICHLOROETHENE	U	5.0	0	2
1,1-DICHLOROETHENE (TOTAL)	U	5.0	0	2
1,2-DICHLOROETHANE	U	5.0	0	2
1,2-DICHLOROPROPANE	U	5.0	0	2
2-BUTANONE	U	10.0	0	2
2-HEXANONE	U	10.0	0	2
4-METHYL-2-PENTANONE	U	10.0	0	2
ACETONE	J	3.5	1	2
BENZENE	U	5.0	0	2
BROMODICHLOROMETHANE	U	5.0	0	2
BROMOFORM	U	5.0	0	2
BROMOMETHANE	U	10.0	0	2
CARBON DISULFIDE	U	5.0	0	2
CARBON TETRACHLORIDE	U	5.0	0	2
CHLOROBENZENE	U	5.0	0	2
CHLOROETHANE	U	10.0	0	2
CHLOROFORM	U	5.0	0	2
CHLOROMETHANE	U	10.0	0	2
CIS-1,3-DICHLOROPROPENE	U	5.0	0	2
DIBROMOCHLOROMETHANE	U	5.0	0	2
ETHYLBENZENE		14.5	1	2
METHYLENE CHLORIDE		9.0	4	2
STYRENE	U	5.0	0	2
TETRACHLOROETHENE	U	5.0	0	2
TOLUENE		16.0	2	2
TRANS-1,3-DICHLOROPROPENE	U	5.0	0	2
TRICHLOROETHENE	U	5.0	0	2
VINYL ACETATE	U	10.0	0	2
VINYL CHLORIDE	U	10.0	0	2
XYLENE (TOTAL)		86.0	68	2

SEMIVOLATILE ORGANICS
TSF CLARIFIER PIT 3

Analyte	Qual-ifier	Mean Conc. (ppb)	Range	Count
1,2,4-TRICHLOROBENZENE	U	95.0	10	2
1,2-DICHLOROBENZENE	U	95.0	10	2
1,3-DICHLOROBENZENE	U	95.0	10	2
1,4-DICHLOROBENZENE	U	95.0	10	2
2,4,5-TRICHLOROPHENOL	U	550.0	100	2
2,4,6-TRICHLOROPHENOL	U	95.0	10	2
2,4-DICHLOROPHENOL	U	95.0	10	2
2,4-DIMETHYLPHENOL	U	95.0	10	2
2,4-DINITROPHENOL	U	550.0	100	2
2,4-DINITROTOLUENE	U	95.0	10	2
2,6-DINITROTOLUENE	U	95.0	10	2
2-CHLORONAPHTHALENE	U	95.0	10	2
2-CHLOROPHENOL	U	95.0	10	2
2-METHYLNAPHTHALENE	U	95.0	10	2
2-METHYLPHENOL	U	95.0	10	2
2-NITROANILINE	U	550.0	100	2
2-NITROPHENOL	U	95.0	10	2
3,3-DICHLOROBENZIDINE	U	200.0	0	2
3-NITROANILINE	U	550.0	100	2
4,6-DINITRO-2-METHYLPHENOL	U	550.0	100	2
4-BROMOPHENYL-PHENYLETHER	U	95.0	10	2
4-CHLORO-3-METHYLPHENOL	U	95.0	10	2
4-CHLOROANILINE	U	95.0	10	2
4-CHLOROPHENYL-PHENYLETHER	U	95.0	10	2
4-METHYLPHENOL	U	95.0	10	2
4-NITROANILINE	U	550.0	100	2
4-NITROPHENOL	U	550.0	100	2
ACENAPHTHENE	U	95.0	10	2
ACENAPHTHYLENE	U	95.0	10	2
ANTHRACENE	U	95.0	10	2
BENZO(A)ANTHRACENE	U	95.0	10	2
BENZO(A)PYRENE	U	95.0	10	2
BENZO(B)FLUORANTHENE	U	95.0	10	2
BENZO(G,H,I)PERYLENE	U	95.0	10	2
BENZO(K)FLUORANTHENE	U	95.0	10	2
BENZOIC ACID	U	550.0	100	2
BENZYL ALCOHOL	U	95.0	10	2
BIS(2-CHLOROETHOXY)METHANE	U	95.0	10	2
BIS(2-CHLOROETHYL)ETHER	U	95.0	10	2
BIS(2-CHLOROISOPROPLY)ETHER	U	95.0	10	2
BIS(2-ETHYLHEXYL)PHTHALATE	J	22.0	14	2
BUTYLBENZYLPHTHALATE		525.0	70	2
CHRYSENE	U	95.0	10	2
DI-N-BUTYLPHTALATE		180.0	0	1
DI-N-BUTYLPHTALATE	J	84.0	0	1
DI-N-OCTYLPHTHALATE	U	95.0	10	2
DIBENZ(A,H)ANTHRACENE	U	95.0	10	2

SEMIVOLATILE ORGANICS
TSF CLARIFIER PIT 3

Analyte	Qual-ifier	Mean Conc. (ppb)	Range	Count
DIBENZOFURAN	U	95.0	10	2
DIETHYLPHTHALATE	U	95.0	10	2
DIMETHYLPHTHALATE	U	95.0	10	2
FLUORANTHENE	U	95.0	10	2
FLUORENE	U	95.0	10	2
HEXACHLOROBENZENE	U	95.0	10	2
HEXACHLOROBUTADIENE	U	95.0	10	2
HEXACHLOROCYCLOPENTADIENE	U	95.0	10	2
HEXACHLOROETHANE	U	95.0	10	2
INDENO(1,2,3-CD)PYRENE	U	95.0	10	2
ISOPHORONE	U	95.0	10	2
N-NITROSO-DI-N-PROPYLAMINE	U	95.0	10	2
N-NITROSODIPHENYLAMINE (1)	J	29.5	7	2
NAPHTHALENE	U	95.0	10	2
NITROBENZENE	U	95.0	10	2
PENTACHLOROPHENOL	U	550.0	100	2
PHENANTHRENE	U	95.0	10	2
PHENOL	U	95.0	10	2
PYRENE	U	95.0	10	2

TIC SEMIVOLATILES
TSF CLARIFIER PIT 3

Analyte	Qual-ifier	Mean Conc. (ppb)	Minimum	Maximum	Range	Count
1-HEXENE,3,5,5-TRIMETHYL	J	88000.00	88000	88000	0	1
BUTANE,2,2,3,3-TETRAMETHYL	J	190000.00	190000	190000	0	1
DECANE,2,4,6-TRIMETHYL	J	300000.00	300000	300000	0	1
DECANE,2,6,7-TRIMETHYL	J	110000.00	110000	110000	0	1
HEXANE,2,2,5-TRIMETHYL	J	110000.00	110000	110000	0	1
NONANE, 2-METHYL-	J	110000.00	110000	110000	0	1
NONANE,2-MRTHYL	J	230000.00	230000	230000	0	1
OCTANE,2,4,6-TRIMETHYL	J	180000.00	180000	180000	0	1
PENTANE,2,2,3,4-TETRAMETHYL	J	285000.00	180000	390000	210000	2
PHENOL,4-(1,1,3,3-TETRAMETHYL	J	530000.00	530000	530000	0	1
PHENOL,4-(2,2,3,3-TETRAMETHYL	J	700000.00	700000	700000	0	1
PHENOL,4-(4,3,3-TETRAMETHYLBU	J	530000.00	530000	530000	0	1
PHENOL,4-CHLORO-2-(PHENYLMETH	J	103500.00	37000	170000	133000	2
PROPANOIC ACID,2-METHYL,-1-(1	J	45000.00	45000	45000	0	1
UNK SUBSTITUTED DECANE	J	51000.00	51000	51000	0	1
UNK SUBSTITUTED HYDROCARBON	J	120000.00	120000	120000	0	1
UNKNOWN	J	132846.15	36000	700000	664000	13
UNKNOWN HYDROCARBON	J	168166.67	61000	380000	319000	6
UNKNOWN SUBST HYDROCARBON	J	240000.00	240000	240000	0	1
[1,1-BIPHENYL]-2-01	J	170000.00	170000	170000	0	1
[1,1-BIPHENYL]-2-OL	J	50000.00	50000	50000	0	1

TIC VOLATILES
TSF CLARIFIER PIT 3

Analyte	Qual-ifier	Mean Conc. (ppb)	Minimum	Maximum	Range	Count
UNSATURATED HYDROCARBON		11.5	8	15	7	2

PESTICIDE ORGANICS
TSF CLARIFIER PIT 3

Analyte	Qual-ifier	Mean Conc. (ppb)	Range	Count
-4,4-DDD	U	1270	860	2
4,4-DDE	U	1270	860	2
4,4-DDT	U	1270	860	2
ALDRIN	U	630	420	2
ALPHA CHLORDANE		8400	0	1
ALPHA CHLORDANE	U	4200	0	1
ALPHA-BHC	U	630	420	2
AROCLOR 1016	U	6300	4200	2
AROCLOR 1221	U	6300	4200	2
AROCLOR 1232	U	6300	4200	2
AROCLOR 1242	U	6300	4200	2
AROCLOR 1248	U	6300	4200	2
AROCLOR 1254	U	12700	8600	2
AROCLOR 1260	U	12700	8600	2
BETHA-BHC	U	630	420	2
DELTA-BHC	U	630	420	2
DIELDRIN	U	1270	860	2
ENDOSULFAN I	U	630	420	2
ENDOSULFAN II	U	1270	860	2
ENDOSULFAN SULFATE	U	1270	860	2
ENDRIN	U	1270	860	2
ENDRIN KETONE	U	1270	860	2
GAMMA CHLORDANE	U	6300	4200	2
GAMMA-BHC	U	630	420	2
HEPTACHLOR	U	630	420	2
HEPTRACHLOR EPOXIDE	U	630	420	2
METHOXYCHLOR	U	6300	4200	2
TOXAPHENE	U	12700	8600	2

RESULTS OF THE INORGANIC ANALYSES
OF THE TSF CLARIFIER PITS

NOTES FOR ORGANICS RESULTS

U -- indicates compound was analyzed for but not detected.

J -- indicates an estimated value. This flag is used when estimating the concentration of tentatively identified compounds or when compound is identified but the concentration is less than the sample quantitation limit.

B -- analyte found in the associated blank as well as in the sample.

D -- identifies all compounds identified in an analysis at a secondary dilution factor.

NOTES FOR INORGANICS RESULTS

U -- indicates compound was analyzed for but not detected.

B -- indicates the reported value is less than the Contract Required Detection Limit (CRDL) but greater than the Instrument Detection Limit (IDL).

E -- indicates a value estimated or not reported due to the presence of interference.

S -- indicates value determined by Method of Standard Addition.

N -- indicates matrix spike sample recovery is not within control limits.

* -- indicates duplicate analysis is not within control limits.

+ -- indicates that the correlation coefficient for Method of Standard Addition is less than 0.995.

INORGANICS
TSF CLARIFIER PIT 1

Analyte	Qual-ifier	Mean Conc. (ppm)	Range	Count
Antimony	U	37.80	1.6	2
Arsenic		42.55	69.3	2
Barium		225.50	79.0	2
Beryllium	U	0.80	0.2	2
Cadmium		16.40	2.4	2
Chromium		279.50	45.0	2
Cobalt		53.80	2.2	2
Copper		641.00	358.0	2
Cyanide	U	4.70	1.2	2
Lead		537.50	611.0	2
Mercury		18.45	9.1	2
Nickel		185.55	202.9	2
Selenium	U	8.95	0.3	2
Silver		12.80	0.0	1
Silver	U	3.70	0.0	1
Thallium	U	0.95	0.1	2
Tin	U	3940.00	1120.0	2
Vanadium		86.40	4.6	2
Zinc		1315.00	330.0	2

INORGANICS
TSF CLARIFIER PIT 3

Analyte	Qual-ifier	Mean Conc. (ppm)	Range	Count
Antimony	U	53.40	18.8	3
Arsenic		29.67	29.1	3
Barium		191.00	0.0	1
Barium	B	59.40	32.8	2
Beryllium	U	1.03	0.5	3
Cadmium		4.10	4.6	2
Cadmium	B	2.00	0.0	1
Chromium		13.57	21.5	3
Cobalt	B	10.00	0.0	1
Cobalt	U	9.65	2.5	2
Copper		39.95	44.3	2
Copper	B	8.60	0.0	1
Cyanide	U	8.07	3.8	3
Lead		61.63	14.1	3
Mercury		47.47	25.1	3
Nickel	U	11.97	6.8	3
Selenium	U	9.37	14.2	3
Silver	U	4.13	2.3	3
Thallium	U	1.33	0.5	3
Tin	U	4980.00	2820.0	3
Vanadium	B	17.50	26.4	2
Vanadium	U	5.40	0.0	1
Zinc		522.00	608.0	3

QC RESULTS OF THE TSF CLARIFIER PITS

FIELD QUALITY CONTROL SAMPLE EVALUATION DESCRIPTION

TRIP BLANKS

Trip blanks are flagged "Possible Contamination" if concentration is above the Instrument Detection Limit (IDL) and is not qualified with a 'J' (see explanation of qualifiers). Otherwise, the samples are flagged "No Contamination".

EQUIPMENT BLANKS

Equipment blanks are flagged "Possible Contamination" if concentration is above the IDL and is not qualified with a 'J' (see explanation of qualifiers). Otherwise, the samples are flagged "No Contamination".

SPLITS

Splits are flagged as out of control if the relative percent difference (RPD) or absolute difference, as appropriate, does not lie within EPA empirically derived limits. If the splits are within these limits, they are flagged as in control. If no limits are available, the splits are flagged as such. If the splits are below detection, then the RPD is not calculated.

The EPA limits for organics used are those presented on the Contract Laboratory Program (CLP) forms and in the CLP Statement of Work (SOW) for matrix spike duplicates. In the case where one of the splits is greater than the IDL and the other less than the IDL, the RPD reported is a minimum value.

For inorganics, the comparison of split data to EPA limits is:

1) RPD compared to 20% when both splits are greater than five times the Contract Required Detection Limit (CRDL) or

2) absolute difference compared to CRDL for case where

a). both splits are between the CRDL and five times the CRDL or

b). one split is between the CRDL and five times the CRDL and the other is greater than five times the CRDL.

In cases where one or both of the splits is less than either the CRDL or the IDL, the sample is flagged "Concentration < CRDL". When the CRDL is not available, the sample is flagged as such. Calculation of these limits is described in the SOW (Exhibit E).

In addition to the above flags, cases where the IDL is greater than the CRDL is also flagged. Under typical conditions, this is a noncompliant item and is included in the validation effort. It was included here for the sake of completeness.

SPIKES

Percent recovery of analytes added to spiked samples is calculated. Because of the use of standards in spike preparation, comparison to EPA limits is not appropriate and manual examination of the recoveries is made.

Spikes are flagged "Possible Contamination" if concentration of analytes not added to the sample is above the IDL and is not qualified with a 'J' (see explanation of qualifiers). Otherwise, these sample/analyte combinations are flagged "No Contamination".

NOTES FOR ORGANICS RESULTS

U -- indicates compound was analyzed for but not detected.

J -- indicates an estimated value. This flag is used when estimating the concentration of tentatively identified compounds or when compound is identified but the concentration is less than the sample quantitation limit.

B -- analyte found in the associated blank as well as in the sample.

D -- identifies all compounds identified in an analysis at a secondary dilution factor.

NOTES FOR INORGANICS RESULTS

U -- indicates compound was analyzed for but not detected.

B -- indicates the reported value is less than the Contract Required Detection Limit (CRDL) but greater than the Instrument Detection Limit (IDL).

E -- indicates a value estimated or not reported due to the presence of interference.

S -- indicates value determined by Method of Standard Addition.

N -- indicates matrix spike sample recovery is not within control limits.

* -- indicates duplicate analysis is not within control limits.

+ -- indicates that the correlation coefficient for Method of Standard Addition is less than 0.995.

EQUIPMENT BLANK EVALUATION
INORGANICS
TSF CLARIFIER PITS

Analyte	Sample ID	Conc. (ppb)	Qual-ifier	Comment
Antimony	TSF118700E	86.5	UEN	No Contamination
Arsenic	TSF118700E	5.6	UWN*	No Contamination
Barium	TSF118700E	24.0	U*E	No Contamination
Beryllium	TSF118700E	2.1	U	No Contamination
Cadmium	TSF118700E	2.4	U*E	No Contamination
Chromium	TSF118700E	7.1	U*E	No Contamination
Cobalt	TSF118700E	17.0	U	No Contamination
Copper	TSF118700E	13.0	U*E	No Contamination
Cyanide	TSF118700E	5.0	U	No Contamination
Lead	TSF118700E	7.0	*	Possible Contamination
Mercury	TSF118700E	0.2	U	No Contamination
Nickel	TSF118700E	24.0	UE	No Contamination
Selenium	TSF118700E	20.5	UN	No Contamination
Silver	TSF118700E	8.3	U	No Contamination
Thallium	TSF118700E	2.2	UN	No Contamination
Tin	TSF118700E	10000.0	U	No Contamination
Vanadium	TSF118700E	11.0	UE	No Contamination
Zinc	TSF118700E	7.8	UE	No Contamination

EQUIPMENT BLANK EVALUATION
ORGANICS
TSF CLARIFIER PITS

Analyte	Sample ID	Conc. (ppb)	Qual-ifier	Comment
1,1,1-TRICHLOROETHANE	TSF118700EE	380		Possible Contamination
1,1,2,2-TETRACHLOROETHANE	TSF118700EE	20	U	No Contamination
1,1,2-TRICHLOROETHANE	TSF118700EE	20	U	No Contamination
1,1-DICHLOROETHANE	TSF118700EE	20	U	No Contamination
1,1-DICHLOROETHENE	TSF118700EE	20	U	No Contamination
1,1-DICHLOROETHENE (TOTAL)	TSF118700EE	110		Possible Contamination
1,2-DICHLOROETHANE	TSF118700EE	20	U	No Contamination
1,2-DICHLOROPROPANE	TSF118700EE	20	U	No Contamination
2-BUTANONE	TSF118700EE	30	U	No Contamination
2-HEXANONE	TSF118700EE	30	U	No Contamination
4-METHYL-2-PENTANONE	TSF118700EE	30	U	No Contamination
ACETONE	TSF118700EE	30	U	No Contamination
BENZENE	TSF118700EE	20	U	No Contamination
BROMODICHLOROMETHANE	TSF118700EE	20	U	No Contamination
BROMOFORM	TSF118700EE	20	U	No Contamination
BROMOMETHANE	TSF118700EE	30	U	No Contamination
CARBON DISULFIDE	TSF118700EE	20	U	No Contamination
CARBON TETRACHLORIDE	TSF118700EE	20	U	No Contamination
CHLOROBENZENE	TSF118700EE	190		Possible Contamination
CHLOROETHANE	TSF118700EE	30	U	No Contamination
CHLOROFORM	TSF118700EE	34		Possible Contamination
CHLOROMETHANE	TSF118700EE	30	U	No Contamination
CIS-1,3-DICHLOROPROPENE	TSF118700EE	20	U	No Contamination
DIBROMOCHLOROMETHANE	TSF118700EE	20	U	No Contamination
ETHYLBENZENE	TSF118700EE	76		Possible Contamination
METHYLENE CHLORIDE	TSF118700EE	280		Possible Contamination
STYRENE	TSF118700EE	20	U	No Contamination
TETRACHLOROETHENE	TSF118700EE	20	U	No Contamination
TOLUENE	TSF118700EE	20	U	No Contamination
TRANS-1,3-DICHLOROPROPENE	TSF118700EE	20	U	No Contamination
TRICHLOROETHENE	TSF118700EE	120		Possible Contamination
VINYL ACETATE	TSF118700EE	30	U	No Contamination
VINYL CHLORIDE	TSF118700EE	30	U	No Contamination
XYLENE (TOTAL)	TSF118700EE	20	U	No Contamination

FIELD SPLIT EVALUATION
INORGANICS
TSF CLARIFIER PIT 1

Analyte	Sample ID	Conc. (ppb)	Qual-ifier	Relative Percent Difference	CRDL	Comment
Antimony	TSF1187011	38600	UEN	.	60.0	IDL > CRDL -- Noncompliance
Antimony	TSF1187012	37000	UEN	.	60.0	IDL > CRDL -- Noncompliance
Arsenic	TSF1187011	77200	+N*	163	10.0	RPD > 20% -- Out of Control
Arsenic	TSF1187012	7900	+N*	163	10.0	RPD > 20% -- Out of Control
Barium	TSF1187011	265000	*E	35	200.0	RPD > 20% -- Out of Control
Barium	TSF1187012	186000	*E	35	200.0	RPD > 20% -- Out of Control
Beryllium	TSF1187011	900	U	.	5.0	IDL > CRDL -- Noncompliance
Beryllium	TSF1187012	700	U	.	5.0	IDL > CRDL -- Noncompliance
Cadmium	TSF1187011	17600	*E	15	5.0	RPD < 20% -- In Control
Cadmium	TSF1187012	15200	*E	15	5.0	RPD < 20% -- In Control
Chromium	TSF1187011	302000	*E	16	10.0	RPD < 20% -- In Control
Chromium	TSF1187012	257000	*E	16	10.0	RPD < 20% -- In Control
Cobalt	TSF1187011	54900		4	50.0	RPD < 20% -- In Control
Cobalt	TSF1187012	52700		4	50.0	RPD < 20% -- In Control
Copper	TSF1187011	820000	*E	56	25.0	RPD > 20% -- Out of Control
Copper	TSF1187012	462000	*E	56	25.0	RPD > 20% -- Out of Control
Cyanide	TSF1187011	5300	U	.	.	CRDL not available
Cyanide	TSF1187012	4100	U	.	.	CRDL not available
Lead	TSF1187011	232000	+*	114	5.0	RPD > 20% -- Out of Control
Lead	TSF1187012	843000	+*	114	5.0	RPD > 20% -- Out of Control
Mercury	TSF1187011	23000		49	0.2	RPD > 20% -- Out of Control
Mercury	TSF1187012	13900		49	0.2	RPD > 20% -- Out of Control
Nickel	TSF1187011	287000	E	109	40.0	RPD > 20% -- Out of Control
Nickel	TSF1187012	84100	E	109	40.0	RPD > 20% -- Out of Control
Selenium	TSF1187011	9100	UN	.	5.0	IDL > CRDL -- Noncompliance
Selenium	TSF1187012	8800	UN	.	5.0	IDL > CRDL -- Noncompliance
Silver	TSF1187011	3700	U	.	10.0	IDL > CRDL -- Noncompliance
Silver	TSF1187012	12800		110	10.0	RPD > 20% -- Out of Control
Thallium	TSF1187011	1000	UWN	.	10.0	IDL > CRDL -- Noncompliance
Thallium	TSF1187012	900	UWN	.	10.0	IDL > CRDL -- Noncompliance
Tin	TSF1187011	4500000	U	.	.	CRDL not available
Tin	TSF1187012	3380000	U	.	.	CRDL not available
Vanadium	TSF1187011	88700	E	5	50.0	RPD < 20% -- In Control
Vanadium	TSF1187012	84100	E	5	50.0	RPD < 20% -- In Control
Zinc	TSF1187011	1480000	N*E	25	20.0	RPD > 20% -- Out of Control
Zinc	TSF1187012	1150000	N*E	25	20.0	RPD > 20% -- Out of Control

FIELD SPLIT EVALUATION
ORGANICS
TSF CLARIFIER PIT 1

Analyte	Sample ID	Conc. (ppb)	Qual-ifier	Relative Percent Difference	RPD Limit	Comment
1,1,1-TRICHLOROETHANE	TSF1187011B	5		46	.	RPD > Limit -- Out of Control
1,1,1-TRICHLOROETHANE	TSF1187012B	8		46	.	RPD > Limit -- Out of Control
1,1,2,2-TETRACHLOROETHANE	TSF1187011B	5	U	.	.	RPD Limit Not Available
1,1,2,2-TETRACHLOROETHANE	TSF1187012B	5	U	.	.	RPD Limit Not Available
1,1,2-TRICHLOROETHANE	TSF1187011B	5	U	.	.	RPD Limit Not Available
1,1,2-TRICHLOROETHANE	TSF1187012B	5	U	.	.	RPD Limit Not Available
1,1-DICHLOROETHANE	TSF1187011B	5	U	.	.	RPD Limit Not Available
1,1-DICHLOROETHANE	TSF1187012B	5	U	.	.	RPD Limit Not Available
1,1-DICHLOROETHENE	TSF1187011B	5	U	.	22	RPD Not Calculable
1,1-DICHLOROETHENE	TSF1187012B	5	U	.	22	RPD Not Calculable
1,1-DICHLOROETHENE (TOTAL)	TSF1187011B	5	U	.	.	RPD Limit Not Available
1,1-DICHLOROETHENE (TOTAL)	TSF1187012B	6		18	.	RPD > Limit -- Out of Control
1,2-DICHLOROETHANE	TSF1187011B	5	U	.	.	RPD Limit Not Available
1,2-DICHLOROETHANE	TSF1187012B	5	U	.	.	RPD Limit Not Available
1,2-DICHLOROPROPANE	TSF1187011B	5	U	.	.	RPD Limit Not Available
1,2-DICHLOROPROPANE	TSF1187012B	5	U	.	.	RPD Limit Not Available
2-BUTANONE	TSF1187011B	10	U	.	.	RPD Limit Not Available
2-BUTANONE	TSF1187012B	10	U	.	.	RPD Limit Not Available
2-HEXANONE	TSF1187011B	10	U	.	.	RPD Limit Not Available
2-HEXANONE	TSF1187012B	10	U	.	.	RPD Limit Not Available
4-METHYL-2-PENTANONE	TSF1187011B	10	U	.	.	RPD Limit Not Available
4-METHYL-2-PENTANONE	TSF1187012B	10	U	.	.	RPD Limit Not Available
ACETONE	TSF1187011B	10	U	.	.	RPD Limit Not Available
ACETONE	TSF1187012B	2	J	.	.	RPD Limit Not Available
BENZENE	TSF1187011B	5	U	.	21	RPD Not Calculable
BENZENE	TSF1187012B	5	U	.	21	RPD Not Calculable
BROMODICHLOROMETHANE	TSF1187011B	5	U	.	.	RPD Limit Not Available
BROMODICHLOROMETHANE	TSF1187012B	5	U	.	.	RPD Limit Not Available
BROMOFORM	TSF1187011B	5	U	.	.	RPD Limit Not Available
BROMOFORM	TSF1187012B	5	U	.	.	RPD Limit Not Available
BROMOMETHANE	TSF1187011B	10	U	.	.	RPD Limit Not Available
BROMOMETHANE	TSF1187012B	10	U	.	.	RPD Limit Not Available
CARBON DISULFIDE	TSF1187011B	5	U	.	.	RPD Limit Not Available
CARBON DISULFIDE	TSF1187012B	5	U	.	.	RPD Limit Not Available
CARBON TETRACHLORIDE	TSF1187011B	5	U	.	.	RPD Limit Not Available
CARBON TETRACHLORIDE	TSF1187012B	5	U	.	.	RPD Limit Not Available
CHLOROBENZENE	TSF1187011B	5	U	.	21	RPD Not Calculable
CHLOROBENZENE	TSF1187012B	5	U	.	21	RPD Not Calculable
CHLOROETHANE	TSF1187011B	10	U	.	.	RPD Limit Not Available
CHLOROETHANE	TSF1187012B	10	U	.	.	RPD Limit Not Available
CHLOROFORM	TSF1187011B	5	U	.	.	RPD Limit Not Available
CHLOROFORM	TSF1187012B	5	U	.	.	RPD Limit Not Available
CHLOROMETHANE	TSF1187011B	10	U	.	.	RPD Limit Not Available
CHLOROMETHANE	TSF1187012B	10	U	.	.	RPD Limit Not Available
CIS-1,3-DICHLOROPROPENE	TSF1187011B	5	U	.	.	RPD Limit Not Available
CIS-1,3-DICHLOROPROPENE	TSF1187012B	5	U	.	.	RPD Limit Not Available
DIBROMOCHLOROMETHANE	TSF1187011B	5	U	.	.	RPD Limit Not Available

FIELD SPLIT EVALUATION
ORGANICS
TSF CLARIFIER PIT 1

Analyte	Sample ID	Conc. (ppb)	Qual-ifier	Relative Percent Difference	RPD Limit	Comment
DIBROMOCHLOROMETHANE	TSF1187012B	5	U	.	.	RPD Limit Not Available
ETHYLBENZENE	TSF1187011B	3	J	.	.	RPD Limit Not Available
ETHYLBENZENE	TSF1187012B	4	J	.	.	RPD Limit Not Available
METHYLENE CHLORIDE	TSF1187011B	86		15	.	RPD > Limit -- Out of Control
METHYLENE CHLORIDE	TSF1187012B	100		15	.	RPD > Limit -- Out of Control
STYRENE	TSF1187011B	5	U	.	.	RPD Limit Not Available
STYRENE	TSF1187012B	5	U	.	.	RPD Limit Not Available
TETRACHLOROETHENE	TSF1187011B	5	U	.	.	RPD Limit Not Available
TETRACHLOROETHENE	TSF1187012B	5	U	.	.	RPD Limit Not Available
TOLUENE	TSF1187011B	11		53	21	RPD > Limit -- Out of Control
TOLUENE	TSF1187012B	19		53	21	RPD > Limit -- Out of Control
TRANS-1,3-DICHLOROPROPENE	TSF1187011B	5	U	.	.	RPD Limit Not Available
TRANS-1,3-DICHLOROPROPENE	TSF1187012B	5	U	.	.	RPD Limit Not Available
TRICHLOROETHENE	TSF1187011B	5	U	.	24	RPD Not Calculable
TRICHLOROETHENE	TSF1187012B	5	U	.	24	RPD Not Calculable
VINYL ACETATE	TSF1187011B	10	U	.	.	RPD Limit Not Available
VINYL ACETATE	TSF1187012B	10	U	.	.	RPD Limit Not Available
VINYL CHLORIDE	TSF1187011B	10	U	.	.	RPD Limit Not Available
VINYL CHLORIDE	TSF1187012B	10	U	.	.	RPD Limit Not Available
XYLENE (TOTAL)	TSF1187011B	37		24	.	RPD > Limit -- Out of Control
XYLENE (TOTAL)	TSF1187012B	47		24	.	RPD > Limit -- Out of Control

FIELD SPLIT EVALUATION
INORGANICS
TSF CLARIFIER PIT 3

Analyte	Sample ID	Conc. (ppb)	Qual-ifier	Relative Percent Difference	CRDL	Comment
Antimony	TSF1187030	52000	UEN	.	60.0	IDL > CRDL -- Noncompliance
Antimony	TSF1187031	44700	UEN	.	60.0	IDL > CRDL -- Noncompliance
Arsenic	TSF1187030	43600	N*	100	10.0	RPD > 20% -- Out of Control
Arsenic	TSF1187031	14500	N*	100	10.0	RPD > 20% -- Out of Control
Barium	TSF1187030	75800	B*E	55	200.0	RPD > 20% -- Out of Control
Barium	TSF1187031	43000	B*E	55	200.0	RPD > 20% -- Out of Control
Beryllium	TSF1187030	1000	U	.	5.0	IDL > CRDL -- Noncompliance
Beryllium	TSF1187031	800	U	.	5.0	IDL > CRDL -- Noncompliance
Cadmium	TSF1187030	2000	B*E	11	5.0	RPD < 20% -- In Control
Cadmium	TSF1187031	1800	*E	11	5.0	RPD < 20% -- In Control
Chromium	TSF1187030	8400	*E	43	10.0	RPD > 20% -- Out of Control
Chromium	TSF1187031	5400	*E	43	10.0	RPD > 20% -- Out of Control
Cobalt	TSF1187030	8400	U	.	50.0	IDL > CRDL -- Noncompliance
Cobalt	TSF1187031	10000	B	17	50.0	RPD < 20% -- In Control
Copper	TSF1187030	17800	*E	70	25.0	RPD > 20% -- Out of Control
Copper	TSF1187031	8600	B*E	70	25.0	RPD > 20% -- Out of Control
Cyanide	TSF1187030	8000	U	.	.	CRDL not available
Cyanide	TSF1187031	6200	U	.	.	CRDL not available
Lead	TSF1187030	68500	S*	10	5.0	RPD < 20% -- In Control
Lead	TSF1187031	62000	+*	10	5.0	RPD < 20% -- In Control
Mercury	TSF1187030	48700		35	0.2	RPD > 20% -- Out of Control
Mercury	TSF1187031	34300		35	0.2	RPD > 20% -- Out of Control
Nickel	TSF1187030	11900	UE	.	40.0	IDL > CRDL -- Noncompliance
Nickel	TSF1187031	8600	UE	.	40.0	IDL > CRDL -- Noncompliance
Selenium	TSF1187030	12300	U+N	.	5.0	IDL > CRDL -- Noncompliance
Selenium	TSF1187031	800	UWN	.	5.0	IDL > CRDL -- Noncompliance
Silver	TSF1187030	4100	U	.	10.0	IDL > CRDL -- Noncompliance
Silver	TSF1187031	3000	U	.	10.0	IDL > CRDL -- Noncompliance
Thallium	TSF1187030	1300	UWN	.	10.0	IDL > CRDL -- Noncompliance
Thallium	TSF1187031	1100	UWN	.	10.0	IDL > CRDL -- Noncompliance
Tin	TSF1187030	4960000	U	.	.	CRDL not available
Tin	TSF1187031	3580000	U	.	.	CRDL not available
Vanadium	TSF1187030	5400	UE	.	50.0	IDL > CRDL -- Noncompliance
Vanadium	TSF1187031	4300	BE	23	50.0	RPD > 20% -- Out of Control
Zinc	TSF1187030	430000	N*E	48	20.0	RPD > 20% -- Out of Control
Zinc	TSF1187031	264000	N*E	48	20.0	RPD > 20% -- Out of Control

FIELD SPLIT EVALUATION
ORGANICS
TSF CLARIFIER PIT 3

Analyte	Sample ID	Conc. (ppb)	Qual-ifier	Relative Percent Difference	RPD Limit	Comment
1,1,1-TRICHLOROETHANE	TSF1187030B	5	U	.	.	RPD Limit Not Available
1,1,1-TRICHLOROETHANE	TSF1187031B	5	U	.	.	RPD Limit Not Available
1,1,2,2-TETRACHLOROETHANE	TSF1187030B	5	U	.	.	RPD Limit Not Available
1,1,2,2-TETRACHLOROETHANE	TSF1187031B	5	U	.	.	RPD Limit Not Available
1,1,2-TRICHLOROETHANE	TSF1187030B	5	U	.	.	RPD Limit Not Available
1,1,2-TRICHLOROETHANE	TSF1187031B	5	U	.	.	RPD Limit Not Available
1,1-DICHLOROETHANE	TSF1187030B	5	U	.	.	RPD Limit Not Available
1,1-DICHLOROETHANE	TSF1187031B	5	U	.	.	RPD Limit Not Available
1,1-DICHLOROETHENE	TSF1187030B	5	U	.	22	RPD Not Calculable
1,1-DICHLOROETHENE	TSF1187031B	5	U	.	22	RPD Not Calculable
1,1-DICHLOROETHENE (TOTAL)	TSF1187030B	5	U	.	.	RPD Limit Not Available
1,1-DICHLOROETHENE (TOTAL)	TSF1187031B	5	U	.	.	RPD Limit Not Available
1,2-DICHLOROETHANE	TSF1187030B	5	U	.	.	RPD Limit Not Available
1,2-DICHLOROETHANE	TSF1187031B	5	U	.	.	RPD Limit Not Available
1,2-DICHLOROPROPANE	TSF1187030B	5	U	.	.	RPD Limit Not Available
1,2-DICHLOROPROPANE	TSF1187031B	5	U	.	.	RPD Limit Not Available
2-BUTANONE	TSF1187030B	10	U	.	.	RPD Limit Not Available
2-BUTANONE	TSF1187031B	10	U	.	.	RPD Limit Not Available
2-HEXANONE	TSF1187030B	10	U	.	.	RPD Limit Not Available
2-HEXANONE	TSF1187031B	10	U	.	.	RPD Limit Not Available
4-METHYL-2-PENTANONE	TSF1187030B	10	U	.	.	RPD Limit Not Available
4-METHYL-2-PENTANONE	TSF1187031B	10	U	.	.	RPD Limit Not Available
ACETONE	TSF1187030B	4	J	.	.	RPD Limit Not Available
ACETONE	TSF1187031B	3	J	.	.	RPD Limit Not Available
BENZENE	TSF1187030B	5	U	.	21	RPD Not Calculable
BENZENE	TSF1187031B	5	U	.	21	RPD Not Calculable
BROMODICHLOROMETHANE	TSF1187030B	5	U	.	.	RPD Limit Not Available
BROMODICHLOROMETHANE	TSF1187031B	5	U	.	.	RPD Limit Not Available
BROMOFORM	TSF1187030B	5	U	.	.	RPD Limit Not Available
BROMOFORM	TSF1187031B	5	U	.	.	RPD Limit Not Available
BROMOMETHANE	TSF1187030B	10	U	.	.	RPD Limit Not Available
BROMOMETHANE	TSF1187031B	10	U	.	.	RPD Limit Not Available
CARBON DISULFIDE	TSF1187030B	5	U	.	.	RPD Limit Not Available
CARBON DISULFIDE	TSF1187031B	5	U	.	.	RPD Limit Not Available
CARBON TETRACHLORIDE	TSF1187030B	5	U	.	.	RPD Limit Not Available
CARBON TETRACHLORIDE	TSF1187031B	5	U	.	.	RPD Limit Not Available
CHLOROBENZENE	TSF1187030B	5	U	.	21	RPD Not Calculable
CHLOROBENZENE	TSF1187031B	5	U	.	21	RPD Not Calculable
CHLOROETHANE	TSF1187030B	10	U	.	.	RPD Limit Not Available
CHLOROETHANE	TSF1187031B	10	U	.	.	RPD Limit Not Available
CHLOROFORM	TSF1187030B	5	U	.	.	RPD Limit Not Available
CHLOROFORM	TSF1187031B	5	U	.	.	RPD Limit Not Available
CHLOROMETHANE	TSF1187030B	10	U	.	.	RPD Limit Not Available
CHLOROMETHANE	TSF1187031B	10	U	.	.	RPD Limit Not Available
CIS-1,3-DICHLOROPROPENE	TSF1187030B	5	U	.	.	RPD Limit Not Available
CIS-1,3-DICHLOROPROPENE	TSF1187031B	5	U	.	.	RPD Limit Not Available
DIBROMOCHLOROMETHANE	TSF1187030B	5	U	.	.	RPD Limit Not Available

FIELD SPLIT EVALUATION
ORGANICS
TSF CLARIFIER PIT 3

Analyte	Sample ID	Conc. (ppb)	Qual-ifier	Relative Percent Difference	RPD Limit	Comment
DIBROMOCHLOROMETHANE	TSF1187031B	5	U	.	.	RPD Limit Not Available
ETHYLBENZENE	TSF1187030B	14		7	.	RPD > Limit -- Out of Control
ETHYLBENZENE	TSF1187031B	15		7	.	RPD > Limit -- Out of Control
METHYLENE CHLORIDE	TSF1187030B	7		44	.	RPD > Limit -- Out of Control
METHYLENE CHLORIDE	TSF1187031B	11		44	.	RPD > Limit -- Out of Control
STYRENE	TSF1187030B	5	U	.	.	RPD Limit Not Available
STYRENE	TSF1187031B	5	U	.	.	RPD Limit Not Available
TETRACHLOROETHENE	TSF1187030B	5	U	.	.	RPD Limit Not Available
TETRACHLOROETHENE	TSF1187031B	5	U	.	.	RPD Limit Not Available
TOLUENE	TSF1187030B	17		13	21	RPD < Limit -- In Control
TOLUENE	TSF1187031B	15		13	21	RPD < Limit -- In Control
TRANS-1,3-DICHLOROPROPENE	TSF1187030B	5	U	.	.	RPD Limit Not Available
TRANS-1,3-DICHLOROPROPENE	TSF1187031B	5	U	.	.	RPD Limit Not Available
TRICHLOROETHENE	TSF1187030B	5	U	.	24	RPD Not Calculable
TRICHLOROETHENE	TSF1187031B	5	U	.	24	RPD Not Calculable
VINYL ACETATE	TSF1187030B	10	U	.	.	RPD Limit Not Available
VINYL ACETATE	TSF1187031B	10	U	.	.	RPD Limit Not Available
VINYL CHLORIDE	TSF1187030B	10	U	.	.	RPD Limit Not Available
VINYL CHLORIDE	TSF1187031B	10	U	.	.	RPD Limit Not Available
XYLENE (TOTAL)	TSF1187030B	120		79	.	RPD > Limit -- Out of Control
XYLENE (TOTAL)	TSF1187031B	52		79	.	RPD > Limit -- Out of Control

TRIP BLANK EVALUATION
ORGANICS
TSF CLARIFIER PITS

Analyte	Sample ID	Conc. (ppb)	Qual-ifier	Comment
1,1,1-TRICHLOROETHANE	624 TRIP BLANK	5	U	No Contamination
1,1,2,2-TETRACHLOROETHANE	624 TRIP BLANK	5	U	No Contamination
1,1,2-TRICHLOROETHANE	624 TRIP BLANK	5	U	No Contamination
1,1-DICHLOROETHANE	624 TRIP BLANK	5	U	No Contamination
1,1-DICHLOROETHENE	624 TRIP BLANK	5	U	No Contamination
1,1-DICHLOROETHENE (TOTAL)	624 TRIP BLANK	5	U	No Contamination
1,2-DICHLOROETHANE	624 TRIP BLANK	5	U	No Contamination
1,2-DICHLOROPROPANE	624 TRIP BLANK	5	U	No Contamination
2-BUTANONE	624 TRIP BLANK	10	U	No Contamination
2-HEXANONE	624 TRIP BLANK	10	U	No Contamination
4-METHYL-2-PENTANONE	624 TRIP BLANK	10	U	No Contamination
ACETONE	624 TRIP BLANK	10	U	No Contamination
BENZENE	624 TRIP BLANK	5	U	No Contamination
BROMODICHLOROMETHANE	624 TRIP BLANK	5	U	No Contamination
BROMOFORM	624 TRIP BLANK	5	U	No Contamination
BROMOMETHANE	624 TRIP BLANK	10	U	No Contamination
CARBON DISULFIDE	624 TRIP BLANK	5	U	No Contamination
CARBON TETRACHLORIDE	624 TRIP BLANK	5	U	No Contamination
CHLOROBENZENE	624 TRIP BLANK	5	U	No Contamination
CHLOROETHANE	624 TRIP BLANK	10	U	No Contamination
CHLOROFORM	624 TRIP BLANK	5	U	No Contamination
CHLOROMETHANE	624 TRIP BLANK	10	U	No Contamination
CIS-1,3-DICHLOROPROPENE	624 TRIP BLANK	5	U	No Contamination
DIBROMOCHLOROMETHANE	624 TRIP BLANK	5	U	No Contamination
ETHYLBENZENE	624 TRIP BLANK	5	U	No Contamination
METHYLENE CHLORIDE	624 TRIP BLANK	3	JB	Possible Contamination
STYRENE	624 TRIP BLANK	5	U	No Contamination
TETRACHLOROETHENE	624 TRIP BLANK	5	U	No Contamination
TOLUENE	624 TRIP BLANK	5	U	No Contamination
TRANS-1,3-DICHLOROPROPENE	624 TRIP BLANK	3	U	No Contamination
TRICHLOROETHENE	624 TRIP BLANK	5	U	No Contamination
VINYL ACETATE	624 TRIP BLANK	10	U	No Contamination
VINYL CHLORIDE	624 TRIP BLANK	10	U	No Contamination
XYLENE (TOTAL)	624 TRIP BLANK	5	U	No Contamination

SPIKE EVALUATION
ORGANICS
TSF CLARIFIER PITS

Analyte	Sample ID	Conc. (ppb)	Qual-ifier	Comment
1,1,1-TRICHLOROETHANE	TSF118700EE	380		Within ERA advisory r
1,1,2,2-TETRACHLOROETHANE	TSF118700EE	20	U	No Interference
1,1,2-TRICHLOROETHANE	TSF118700EE	20	U	No Interference
1,1-DICHLOROETHANE	TSF118700EE	20	U	No Interference
1,1-DICHLOROETHENE	TSF118700EE	20	U	No Interference
1,1-DICHLOROETHENE (TOTAL)	TSF118700EE	110		Possible Interference
1,2-DICHLOROETHANE	TSF118700EE	20	U	No Interference
1,2-DICHLOROPROPANE	TSF118700EE	20	U	No Interference
2-BUTANONE	TSF118700EE	30	U	No Interference
2-HEXANONE	TSF118700EE	30	U	No Interference
4-METHYL-2-PENTANONE	TSF118700EE	30	U	No Interference
ACETONE	TSF118700EE	30	U	No Interference
BENZENE	TSF118700EE	20	U	No Interference
BROMODICHLOROMETHANE	TSF118700EE	20	U	No Interference
BROMOFORM	TSF118700EE	20	U	No Interference
BROMOMETHANE	TSF118700EE	30	U	No Interference
CARBON DISULFIDE	TSF118700EE	20	U	No Interference
CARBON TETRACHLORIDE	TSF118700EE	20	U	No Interference
CHLOROBENZENE	TSF118700EE	190		Within ERA advisory r
CHLOROETHANE	TSF118700EE	30	U	No Interference
CHLOROFORM	TSF118700EE	34		Within ERA advisory r
CHLOROMETHANE	TSF118700EE	30	U	No Interference
CIS-1,3-DICHLOROPROPENE	TSF118700EE	20	U	No Interference
DIBROMOCHLOROMETHANE	TSF118700EE	20	U	No Interference
ETHYLBENZENE	TSF118700EE	76		Within ERA advisory r
METHYLENE CHLORIDE	TSF118700EE	280		Within ERA advisory r
STYRENE	TSF118700EE	20	U	No Interference
TETRACHLOROETHENE	TSF118700EE	20	U	No Interference
TOLUENE	TSF118700EE	20	U	No Interference
TRANS-1,3-DICHLOROPROPENE	TSF118700EE	20	U	No Interference
TRICHLOROETHENE	TSF118700EE	120		Within ERA advisory r
VINYL ACETATE	TSF118700EE	30	U	No Interference
VINYL CHLORIDE	TSF118700EE	30	U	No Interference
XYLENE (TOTAL)	TSF118700EE	20	U	No Interference